UNIV. OF
TORONTO

BINDING LIST MAY 15 1924.

Digitized by the Internet Archive
in 2011 with funding from
University of Toronto

http://www.archive.org/details/saejournal13soci

Technol
S.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIII July, 1923 No. 1

M1704
4.6.24

Chronicle and Comment

A Few Important Facts

A National highway-system will reduce the cost of living and promote National security.

The car-owner is his own "engineer," traffic manager and also president of his transportation line.

About 90 per cent of the Country's taxes are paid by owners of automobiles.

Only 9 per cent of all the cars are in cities of 500,000 or over.

Every day in every way our cars grow better and better.

Oil-Films in High-Speed Bearings

IN *Engineering* (London) for March 3, 1922, a very interesting report of tests made at the College of Technology, Manchester, England, to determine the thickness and resistance of oil-films in high-speed bearings is presented. This article, which will be found on p. 101, is reprinted in full because it presents one of the few successful attempts to measure the thickness of oil-films in bearings, and because it verifies certain features of the theory of bearing lubrication not before subjected to direct experiment. While written from the point of view of steam turbine lubrication, the results are equally applicable to the lubrication of shaft bearings in general.

Service and Foreign Membership

IN view of the disproportionately small salaries paid engineers employed by the Government and of the fact that members of the Society residing abroad generally cannot attend meetings of the Society, the Constitution of the Society was amended some years ago to provide for the election of Service Members and Foreign Members. A Service Member is defined as a person 26 years of age or over, engaged exclusively with the United States Government; and a Foreign Member as a resident of countries other than the United States, Canada, Mexico or Cuba. The required qualifications for election to either grade are the same as those for full Member grade. A full Member who has become eligible for either the Service or the Foreign grade may upon written request be transferred to such grade. After the transfer, the lower annual dues of the grades apply, that is $10, this being the amount of the annual dues that Junior members pay. In turn, the Constitution provides that Service and Foreign Members shall give due notification of their termination of connection with the Service or change of residence to territory not designated as foreign.

All full Members of the Society who are eligible for Service or Foreign grade, and wish to be transferred accordingly, should notify the office of the Society in due course, and in any event before Oct. 1 next, the beginning of the 1924 fiscal year.

Government Purchasing Specifications

AT the call of Herbert Hoover, secretary of the Department of Commerce, a meeting was held in the City of Washington last month to consider the matter of broad cooperation in the standardization and improvement of specifications for use by national, state, municipal, county and institutional purchasing departments. Among the organizations represented, in addition to the Society, were the American Engineering Standards Committee, American Society for Testing Materials, the National Association of Purchasing Agents, the Hotel Association, the National Association of Manufacturers, the United States Department of Commerce and the American Electrical Association. It is the intention of the Government to give particular attention in this connection to those commodities in which there is the largest volume of trade, and to coordinate governmental and commercial demands. One feature of the movement is the publication of a book of specifications, standards and simplifications, many of which, of course, already exist. The Department of Commerce bureau will submit the specifications to industry for comment.

It is appreciated that one of the most urgent needs in connection with standardization and specification work is education as to the existence and the merit of formulated recommendations for practice. What Secretary Hoover proposes is to establish a clearing-house on the whole general question of Government specifications, seeking full cooperation from industry and the moral support of commercial associations, as well as the essential service of technical bodies. Revision of Government specifications will be made as promptly as possible when necessary. Obviously, industry should lead largely in new fundamental specification work, and no movement can be forced effectively beyond the point justified by the actual evolutionary results of widespread engineering, scientific and commercial effort. Thoroughgoing work is always

needed in this connection. There is much room for improvement in the working relations of the purchasing and the engineering elements of industry. Government activities of the kind indicated redound to the general benefit in that, if for no other reason, they frequently cause more effective cooperation between industrial bodies.

The Printed Word

THERE is a certain psychological effect that causes the average individual to attach more importance to the printed than to the typewritten word. To be specific, Society members are inclined to feel that tentative recommendations proposed by Divisions or even Subdivisions of the Standards Committee represent the final Society action, merely because such recommendations appear in printed form in THE JOURNAL.

After a recommendation has appeared in THE JOURNAL in a general article on Tentative Standardization Work, it frequently is circularized among engineers by letter with a definite request for comment. Many criticisms that merit consideration may result, often causing revisions of the tentative proposals. Very few adverse criticisms are received, however, as a consequence of publication in THE JOURNAL, although many favorable comments and inquiries are received in reference to the work in progress.

It is the policy of the Society to give currently through THE JOURNAL comprehensive information on the activities of the Divisions of the Standards Committee. Members of the Society should appreciate, however, that so far as the Standards Committee is concerned, reports or recommendations have no irrevocable Society standing prior to approval at a duly called meeting of the Society. Through THE JOURNAL Society members receive ample opportunity to comment on all recommendations that may or may not eventually become S. A. E. Standards and Recommended Practices. The printed word is used because it is cheaper to circularize the Society members by use of it rather than by general circular letters.

The "Licensing" of Engineers

BY direction of the Council, a general letter was sent to the members recently on the subject of the laws that have been passed in a score of States providing in general that engineers doing public or private engineering work of a responsible nature shall be required to register, paying fees of varying amounts up to $25 for first registration.

The purpose of the Council was to serve the members by calling their attention to the subject generally, for the reason that to a surprising extent engineers have been unaware of the existence of these laws, most of which have been in legal effect for some time. A great difference of opinion naturally exists as to the advisability, fairness and effectiveness of the laws. Many stress the fact that the licensing practice in various professions has not been highly beneficial so far as the ability and integrity of their members as a whole are concerned. Some feel that engineers need adequate protection and that suitable laws would provide this as well as tend to increase the remuneration for their work. One member expresses the opinion that "for the training, intelligence and hard work that he does, the engineer is the most underpaid man." Another states, "The idea of the laws is to protect the public against 'malicious' engineering, but they do not in any way provide the public with means to assure that sound, conservative and proved engineering talent will be at its command." Of course, the political aspect of the licensing of engineers is a large factor.

The fact is that there is a wide divergence of opinion, as well as greatly varying information, on the whole question among engineers. The question is a very broad one. This is the reason that the engineering profession has been anything but distinctly articulate in definite attitude toward and expression of opinion on the matter of the laws in question, through engineering societies or affiliated bodies. There is very little evidence of injury to the public from poor work by engineers.

It is understood that the scope of the law of the State of New York passed some time ago, requiring the registration of engineers, has been much restricted owing to the passage recently of a bill stipulating that men holding positions of a certain class with companies engaged in interstate commerce shall not be required to register.

Capitalize Truck Operators Experience

SEVERAL educational institutions have addressed inquiries to the Society asking for recommendations of authoritative textbooks on commercial automotive transportation. These institutions are finding a demand for comprehensive courses for motor-transport engineers. It has been necessary in every instance to reply that no thorough and scientific treatise has been prepared, where the knowledge and experience of successful motor-transportation operators may be found assembled in concrete form. This situation brings to mind the importance of our commercial vehicle engineers turning their attention to the operating end of the business. This is more particularly true of freight than passenger traffic, for we find the two companies who pioneered motorbus and taxicab transportation both firmly established as operators in their respective fields. They have learned the lessons of operation and are in a position to pass them on to purchasers of their equipment.

The construction of sound operation practice in the truck field has been left largely to the operator to work out. Sometimes he has had the assistance of the truck builder's sales department, but seldom has he been afforded engineering guidance. Many of the studies made by operators represent well-planned, productive pieces of research that have led to the accomplishment of cheaper transportation and the establishment of the motor truck and the motorbus as efficient commercial carriers. This work of the operator is responsible as much as any other factor, for the apparent impetus given automotive transportation in the past year.

The truck builder and his engineers must get closer to the operating end of motor transport. Design and operation are so closely allied that this intimate relation is essential to the success of the business. Engineers must attend operators' conventions; they must visit and consult with the operators of large fleets; they must see the effect of usage on their vehicles by personal visits to large maintenance stations. Suitable loading and unloading devices cannot be visualized in one's office; accessibility cannot be carried to the ultimate state on the drafting board, or even in the experimental shop. Personal impressions on the spot give one a new vision and an incentive to progress. They enable us to keep in advance of the art rather than merely keeping pace with it. Let us mix more personal observation of truck operation with our engineering thought. Every trip, every visit, every inspection will enable us to carry home some one impression that will pay the expense bill and usually it will be an idea that could never have germinated within our own four walls. When we have the operator's picture and his experience let us put it into concrete form where it may be available for others.

Economic Motor-Fuel Volatility

By Stephen M. Lee[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs and Charts

THE paper is a progress report supplementing a previous report made by R. E. Carlson on the same subject and covers further investigations made by the Bureau of Standards to secure data that can be used as a basis for estimating the effect of a change in the gasoline volatility on the fuel-consumption of cars now in service throughout the United States. Actual tests began in August, 1922, to determine the effect of four fuels of different characteristics on the number of car-miles obtainable per gallon of fuel, as well as on the crankcase-oil dilution. The earlier paper discussed tests run in summer time. The present paper treats those run under winter conditions. Observations also were made on an engine which was set-up and operated in the laboratory under test conditions.

Descriptions are given of the fuels used, the test-cars, the apparatus, the tests and the test methods. The paper also covers a continuation of the crankcase-oil-dilution investigation, with appropriate accompanying data. The results are discussed briefly.

THIS paper is a progress report of the fuel investigation now being conducted by the Bureau of Standards in cooperation with the American Petroleum Institute, the National Automobile Chamber of Commerce and the Society of Automotive Engineers. This investigation was undertaken to secure data to be used in estimating the effect of changes in gasoline volatility, within a given range, upon the performance of the automobiles now in service in this country. The range of volatility was determined by the specifications of four test-fuels selected as described in previous reports. While fuel economy was the phase of car performance chiefly considered, flexibility of operation and crankcase dilution were included as having an important bearing on the problem.

The primary reason for this investigation arises from the difficulty of meeting the rapidly increasing demand for motor fuel from the crude-oil production that has been increasing far less rapidly. According to the figures given by Dr. Van H. Manning in a paper at the Second Annual Meeting of the American Petroleum Institute, during the 5-year period from 1914 to 1919 there was an increase in automobile registration of more than 300 per cent, an increase in gasoline production of over 200 per cent and an increase in crude-oil production of but 42 per cent. This increased production of gasoline has been made possible by refining a greater proportion of the crude oil produced, by the use of more efficient oil-refinery distillation-equipment, by the addition of casinghead gasoline, by the employment of the cracking process and by including in the gasoline increasing amounts of less volatile fractions. This last method is the most important and in it lies the reason for this investigation.

These less volatile hydrocarbons possess somewhat greater energy per unit volume than the more volatile, but the current opinion is that this energy is not so readily or efficiently transformed into useful work in existing automobile engines as is the case with the more volatile distillates. In fact, it has been held that the economic limit has been reached; that a further increase

[1] Jun. S. A. E.—Assistant mechanical engineer, automotive power-plants section, Bureau of Standards, City of Washington.

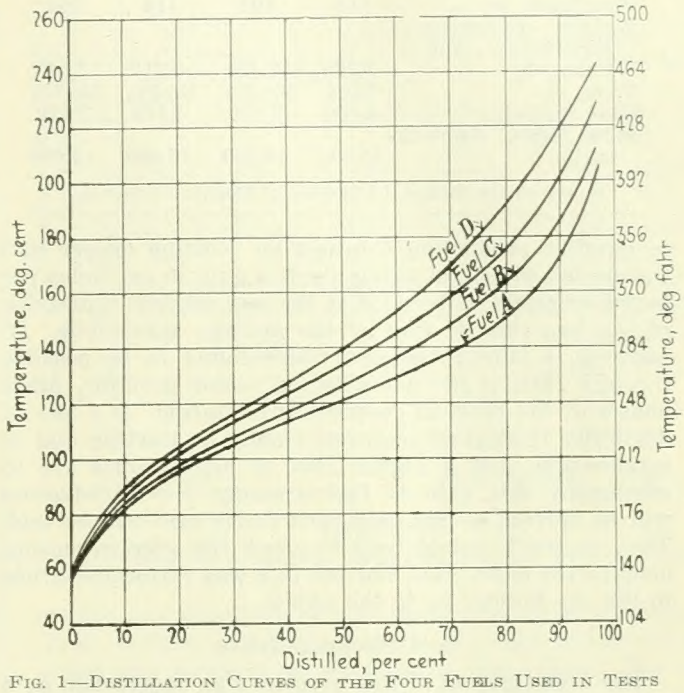


Fig. 1—Distillation Curves of the Four Fuels Used in Tests

TABLE 1—PHYSICAL CHARACTERISTICS OF THE FOUR TEST-FUELS

	Fuel							
	A		*B*		*C*		*D*	
	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.
Distillation, Initial	49.0	120	52.0	126	51.5	125	54.5	130
10 Per Cent	83.0	181	83.5	182	84.5	185	89.0	192
20 Per Cent	94.0	201	96.3	205	102.0	216	104.5	221
30 Per Cent	105.0	221	106.7	225	113.5	237	116.0	241
40 Per Cent	113.5	237	116.3	241	124.5	257	128.0	262
50 Per Cent	121.0	250	126.2	259	134.0	275	139.0	282
60 Per Cent	130.0	266	136.0	277	145.0	293	153.0	307
70 Per Cent	139.5	284	148.0	298	159.0	318	170.5	338
80 Per Cent	149.5	302	163.7	327	176.5	351	194.0	381
85 Per Cent	158.0	316	172.0	342	186.0	367	204.0	399
90 Per Cent	171.5	342	185.0	365	201.0	394	218.5	426
95 Per Cent	192.0	378	203.0	397	218.0	424	233.0	452
End, or High Point	206.5	403	214.0	417	229.5	446	244.5	472
Average Boiling-Point	121	250	125	257	135	275	142	288
Equilibrium Temperature[2]	151	304	163	325	176	349	192	378
Dew-Point, 12 to 1 Mixture[2]	11	52	31	88	47	117	67	153
Average Molecular Weight[2]	111.5		114.0		119.5		123.5	
Specific Gravity at 26 Deg.Cent.(78.5 Deg. Fahr)	0.727		0.733		0.736		0.740	
Index of Refinement, (26 deg. Cent.=78.5 Deg. Fahr.)	1.4110		1.4110		1.4150		1.4165	
Viscosity at 26 Deg. Cent. (78.5 Deg. Fahr.), centipoises	0.527		0.533		0.577		0.592	
Doctor Test	Sweet		Sweet		Sweet		Sweet	
Unsaturated Compounds, per cent	5.5		6.5		6.0		6.0	
Moisture Content	None		None		None		None	
Acidity	None		None		None		None	
Reaction Test	None		None		None		None	

[2] Wilson's Method.

TABLE 2—CHARACTERISTICS OF TEST-CARS USED

Car	*W*	*X*	*Y*	*Z*
Year	1920	1920	1920	1920
Number of Cylinders	6	4	4	4
Bore, in.	3⅜	3 11/16	3⅞	3¾
Stroke, in.	4½	4	4½	4
Piston Displacement, cu. in.	241.6	171.0	212.0	177.0
Power Rating[1], hp.	27.30	21.75	24.03	22.50
Wheelbase, in.	118	102	114	100
Weight, Including Equipment and Crew, lb.	3,760	2,450	3,210	2,335
Tires, in.	33x4	30x3½	32x3½	30x3½
Gear-Ratio	4.000	3.670	4.166	3.630
Miles Run, Approximate	15,000	10,000	15,000	12,000

[1] Based on the National Chamber of Commerce formula.

in gasoline production obtained by "cutting deeper into the crude" would not bring about a gain in car miles per barrel of crude oil because of the less efficient utilization of the less volatile fuel by the average automobile. If, however, a substantial gain were found to be possible through raising the end-point of motor gasoline, other phases of the problem deserve consideration. If a loss of flexibility in engine operation, chiefly in starting and in acceleration, and a higher cost of maintenance are to accompany this gain in fuel economy, less satisfaction will be derived by car users and fewer cars will be sold. This, in itself, would tend to check the ever-increasing demand for motor fuel, but not in a way attractive either to the car builder or to the public.

Summer Road-Tests

The investigation of this problem was undertaken on a cooperative basis by the Bureau of Standards in the spring of 1922. The results of the tests conducted during that year were presented at the 1922 Annual Meeting of the American Petroleum Institute and at the 1923 Annual Meeting of the Society. The work had consisted chiefly of road-tests under warm-weather conditions, using four cars of makes that were estimated to represent 75 per cent of the total number of cars in use and four specified fuels of varying volatility. Descriptions of these cars and fuels will be found in Tables 1 and 2 and in Fig. 1.

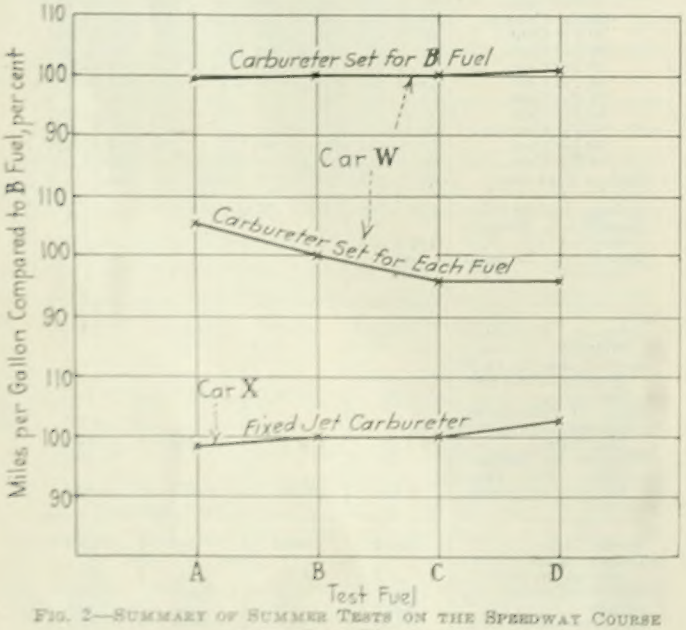


FIG. 2—SUMMARY OF SUMMER TESTS ON THE SPEEDWAY COURSE WITH CARS *W* AND *X*

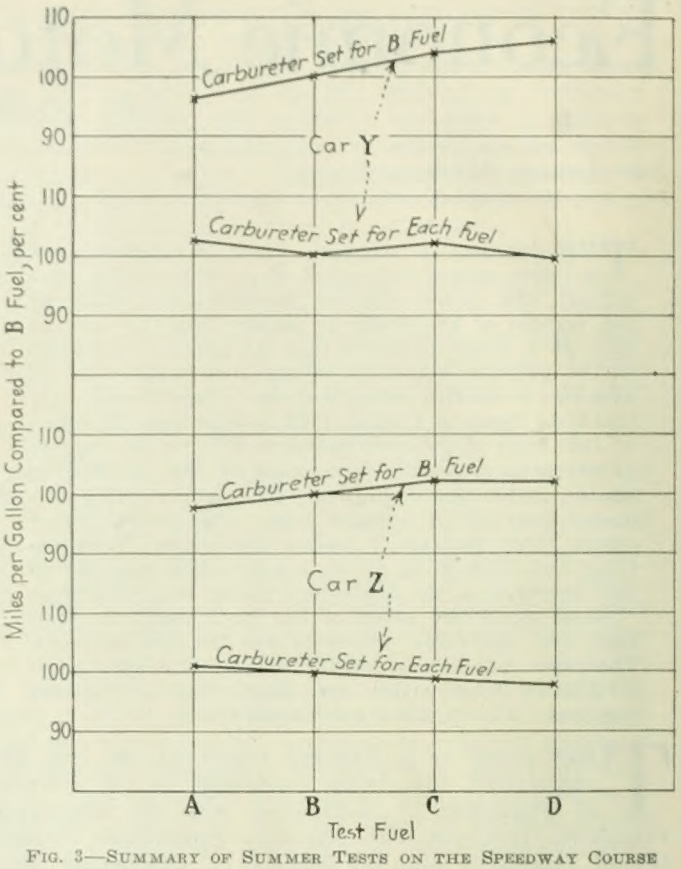


FIG. 3—SUMMARY OF SUMMER TESTS ON THE SPEEDWAY COURSE WITH CARS *Y* AND *Z*

Laboratory work with the engine of the car in most general use was undertaken upon the completion of the road-tests.

The results of the summer road-tests on the Speedway course are summarized in Figs. 2 and 3. The conclusions drawn from these results are (*a*) that under summer weather conditions the differences in fuel consumption obtained with the four test-fuels were much smaller than the differences in the estimated possible production of these test-fuels by current methods as indicated in Table 3, and (*b*) that the results were sensitive to small changes in carbureter adjustment. This sensitiveness is illustrated by the fact that, with a fixed adjustment, better economy was obtained with the less volatile fuels; whereas, when the carbureters were adjusted for each fuel, somewhat better economy was obtained with the more volatile fuels.

The results of the road tests for crankcase dilution indicate that there was a greater rate of dilution with the less volatile fuels.

The Advisory Committee representing the American Petroleum Institute, the National Automobile Chamber of Commerce and the Society of Automotive Engineers, then decided to continue this cooperative program so as

TABLE 3—ESTIMATED PRODUCTION OF FOUR TEST-FUELS, COMPARED WITH GRADE-*B* FUEL

Refiner	Fuel *A*	Fuel *B*	Fuel *C*	Fuel *D*
1	81	100	114	128
2	91	100	111	124
3	83	100	113	122
4	84	100	115	133
5	90	100	112	145
Average	86	100	113	130

to compare the fuels under winter conditions. It was the desire of the Committee that the scope of the program be broadened so as to include a study of those conditions of operation that have a major influence on economy, dilution, acceleration and starting.

In carrying out this program, an effort has been made first to obtain data that would identify those conditions under which differences between the fuels would be most apparent, and then to obtain indications of the relative magnitude and importance of such differences. Upon the completion of this survey, it was planned to investigate more thoroughly the factors controlling these more important differences. Up to the time of this report, the conditions under which differences in the fuels affect

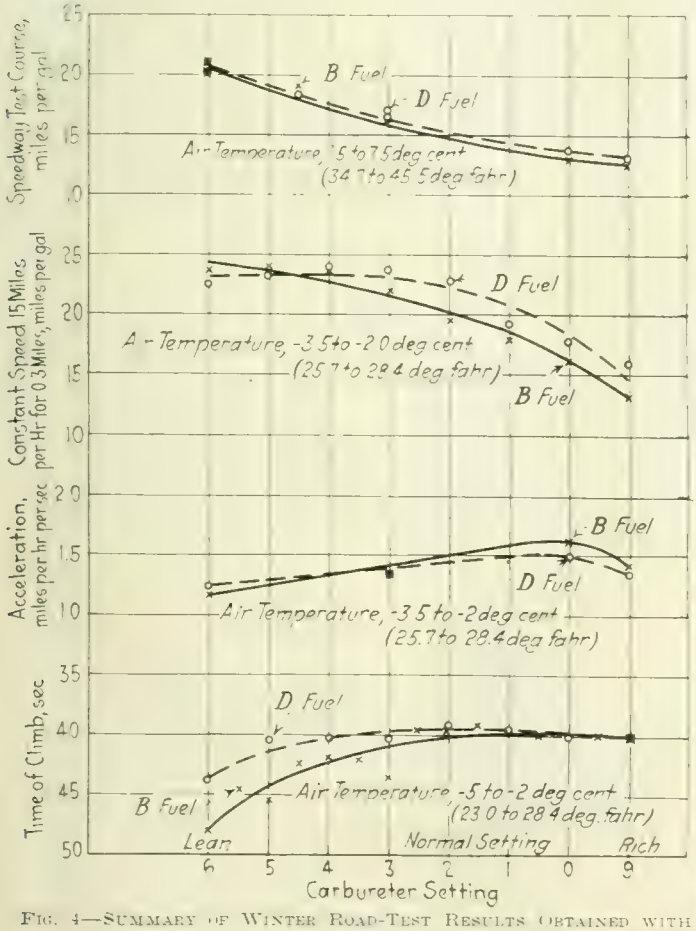

Speedway Test Course, miles per gal
B Fuel
D Fuel
Air Temperature, 5 to 7.5 deg cent (34.7 to 45.5 deg fahr)
Constant Speed 15 Miles per Hr. for 0.3 Miles, miles per gal
D Fuel
A - Temperature, -3.5 to -2.0 deg cent (25.7 to 29.4 deg fahr)
B Fuel
Acceleration, miles per hr per sec
B Fuel
D Fuel
Air Temperature, -3.5 to -2 deg cent (25.7 to 28.4 deg fahr)
Time of Climb, sec
D Fuel
B Fuel
Air Temperature, -5 to -2 deg cent (23.0 to 28.4 deg fahr)
Lean
Normal Setting
Rich
Carbureter Setting

Fig. 4—Summary of Winter Road-Test Results Obtained with Car W

economy at constant speed and load and crankcase dilution have been identified. Similar surveys of the conditions of acceleration and ease of starting are now in progress. In the survey herein reported, gaps may therefore be apparent, which it is hoped can be filled after subsequent work.

Winter Road-Tests

The winter road-tests were made with cars *W* and *Z* and with fuels *B* and *D*. The cars were driven over the Speedway test-course of 3.2 miles in the same manner as in the summer runs. It will be remembered that this procedure involved successive accelerations or decelerations at 0.1-mile intervals. However, these winter runs were made at five different carbureter settings; whereas the summer runs were made with but two. A fuel-consumption comparison over a wide range of carbureter settings was secured thereby. Level-road accel-

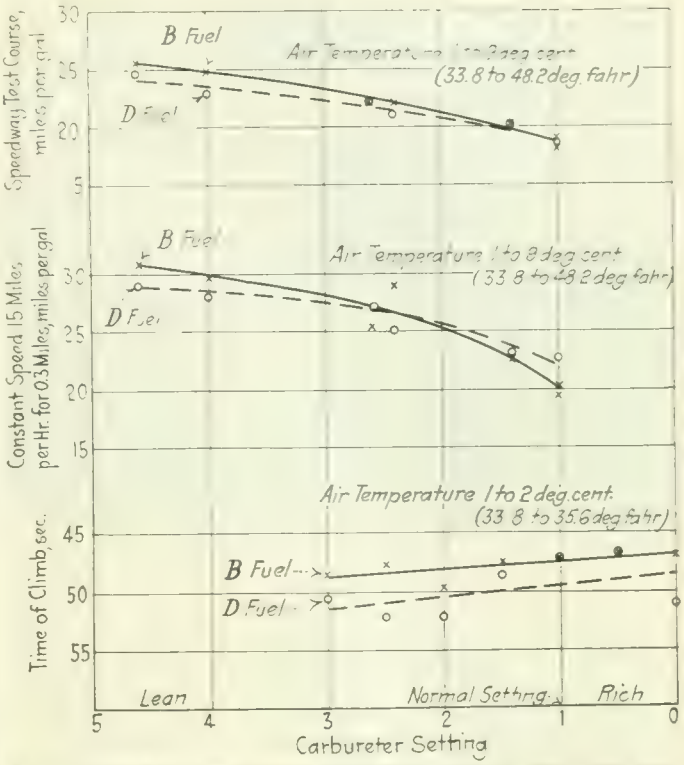

Speedway Test Course, miles per gal
B Fuel
Air Temperature 1 to 2 deg cent (33.8 to 48.2 deg fahr)
D Fuel
Constant Speed 15 Miles per Hr. for 0.3 Miles, miles per gal
B Fuel
Air Temperature 1 to 8 deg cent (33.8 to 48.2 deg fahr)
D Fuel
Air Temperature 1 to 2 deg cent (33.8 to 35.6 deg fahr)
Time of Climb, sec
B Fuel
D Fuel
Lean
Normal Setting
Rich
Carbureter Setting

Fig. 5—Summary of Winter Road-Test Results Obtained with Car Z

eration and hill-climbing runs were made also to identify these carbureter settings and to compare the available power and acceleration when using these fuels. The air temperature during these runs varied from —5 to +7 deg. cent. (23 to 45 deg. fahr.).

The results of these tests shown in Figs. 4 and 5 are erratic, probably due to the wide variation in engine temperatures and due to wind. They do not evidence consistent and significant differences in fuel economy or any other phase of performance as between the test-fuels. The apparent differences are that at constant speed and with very lean carbureter-settings the fuel consumption with *B* fuel is less than with *D* fuel, but that the reverse is true at carbureter settings for normal use. This may be due to the fact that a leaner mixture is obtained with

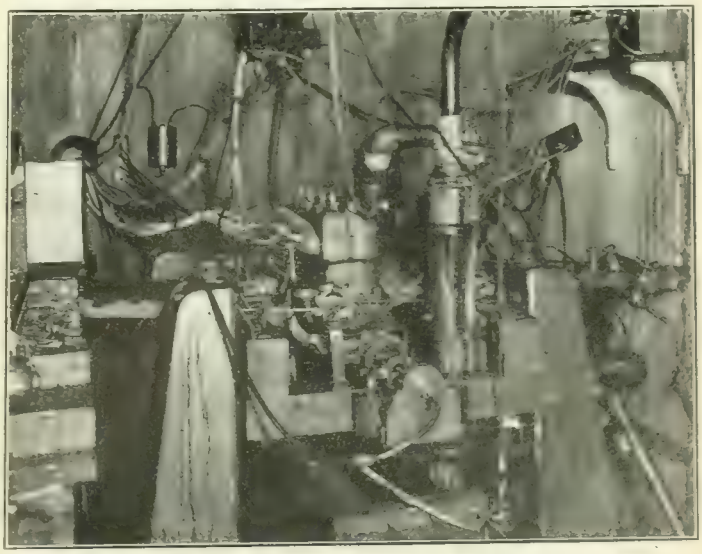


Fig. 6—End View of the Engine from Car Z Being Tested in the Laboratory

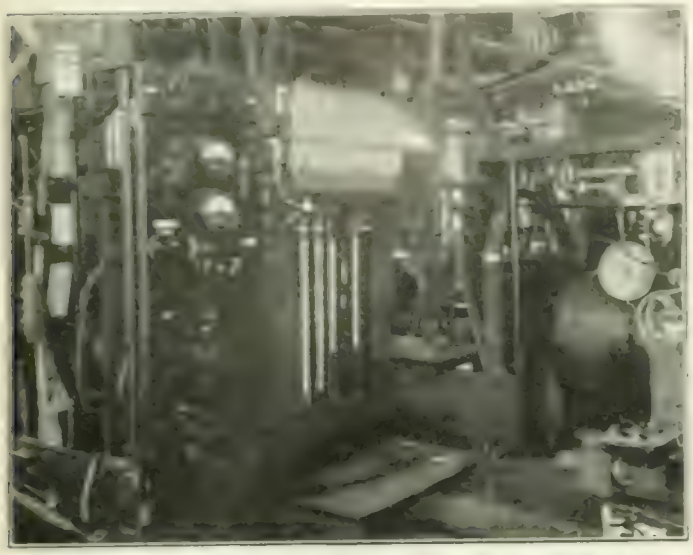


Fig. 5 Another View of the Laboratory Set-Up, Showing the Dynamometer at the Left

D than with *B* fuel at a given carbureter-setting because of the greater viscosity of the *D* fuel. This may also be the explanation of the differences in fuel consumption at fixed carbureter-settings, found in the summer test-runs. Further consideration will be given this phenomenon in the discussion of the laboratory tests.

The results of the winter road-tests are then in general agreement with those of the summer test. For the foregoing reason and because of the impracticability of making a study of the relative effects of the various operating conditions when all the conditions are varying widely, it was decided to concentrate time and effort upon the engine section in the laboratory. The easy control and the accurate measurement of the temperatures, the speed and the load possible in such a set-up offered a much better opportunity for studying the factors that dominate in the effect of fuel volatility upon fuel consumption, crankcase dilution and the like.

Laboratory Tests

Photographs of the engine set-up are shown in Figs. 6, 7 and 8. As will be seen in Fig. 7, a disc was mounted

Fig. 6 Another View of the Laboratory Set-Up

on the end of the armature shaft of the dynamometer so that the inertia load of the shaft, the armature and the disc is approximately equal to that of the car *Z* from which the engine was taken.

Fuel Consumption Tests and Results

Many trial runs were made with the four test-fuels under conditions covering a wide range of air temperature, circulating-water temperature, mixture-ratio, speed and load. The runs constituting the most complete set were with *B* and with *D* fuel, at full and at part load at engine speeds of 500 and 800 r.p.m. and at full load only at 1200 r.p.m. for each fuel, respectively. Five carbureter-settings were used for each run. The temperature of the outlet jacket-water was maintained constant at 10 deg. cent. (50 deg. fahr.) and that of the carbureter air was varied from —5 to +65 deg. cent. (23 to 149 deg. fahr.).

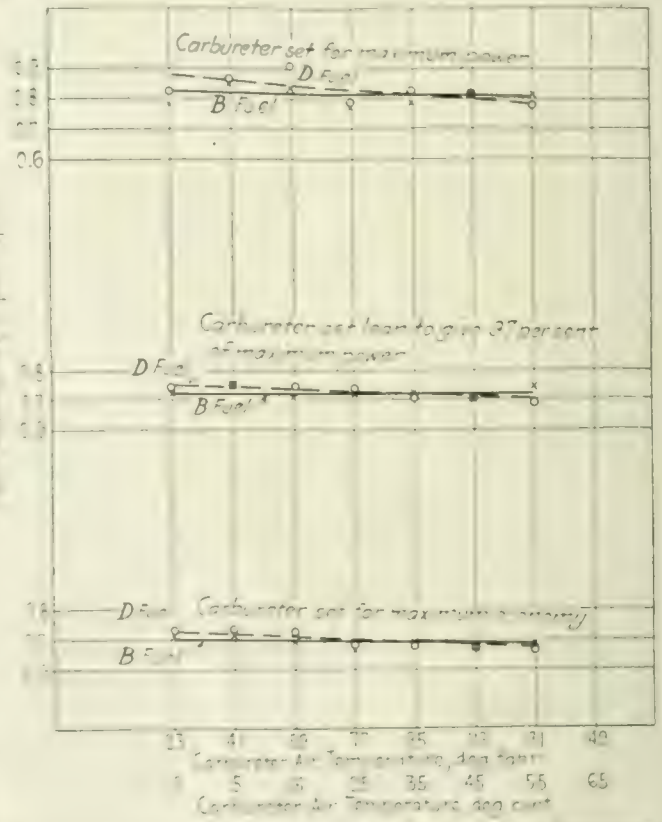


Fig. 9 Comparison of the Amounts of *B* and *D* Fuel Consumed at a Speed of 500 R.P.M. and Full Throttle

With each speed, load, air temperature and fuel, a mixture-ratio run was made; that is, the carbureter was adjusted for what appeared to be a maximum-power mixture, and the fuel consumption was taken with that setting. Then, two leaner and two richer settings were used also.

The results of these fuel-consumption tests are given in Figs. 9 to 13 and include full-throttle operation at 500, 800 and 1200 r.p.m. and part-throttle operation at 500 and 800 r.p.m. The power output is not given, because it was approximately the same with either fuel. There was, of course, greater power-output at the lower air-temperatures.

It can be seen readily that there usually is no difference in fuel consumption as between the test-fuels *B* and *D* at either maximum-power or maximum-economy carbureter-settings. There is one exception. The results of runs at 500 r.p.m., at part load, shown in Fig. 12, in-

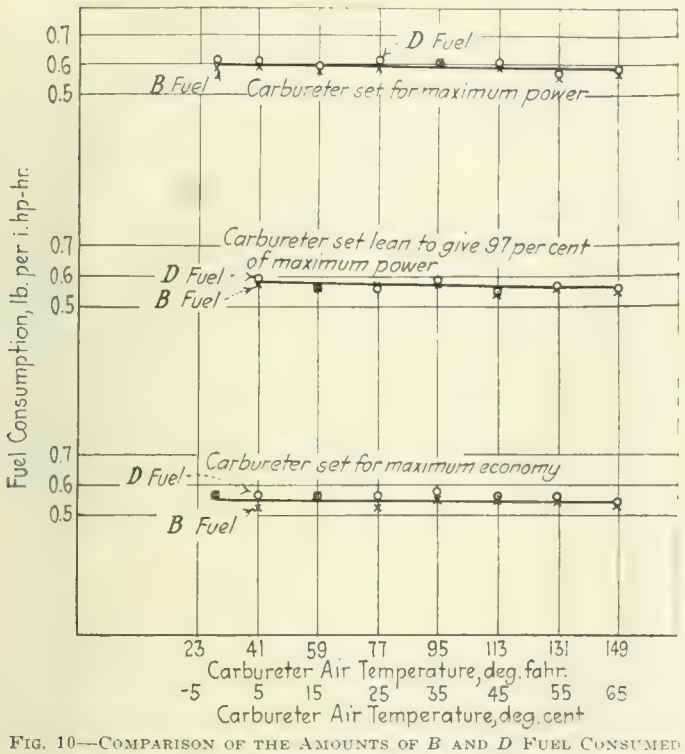

D Fuel
B Fuel
Carbureter set for maximum power
Carbureter set lean to give 97 per cent of maximum power
Carbureter set for maximum economy
Fuel Consumption, lb. per i.hp-hr
Carbureter Air Temperature, deg. fahr.
Carbureter Air Temperature, deg. cent

FIG. 10—COMPARISON OF THE AMOUNTS OF *B* AND *D* FUEL CONSUMED AT A SPEED OF 800 R.P.M. AND FULL THROTTLE

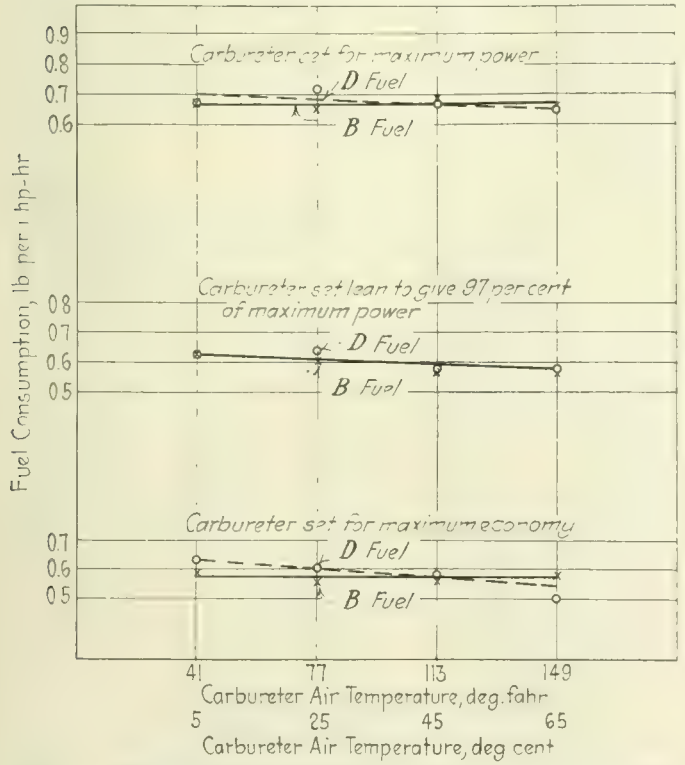

Carbureter set for maximum power
D Fuel
B Fuel
Carbureter set lean to give 97 per cent of maximum power
Carbureter set for maximum economy
Fuel Consumption, lb per i hp-hr
Carbureter Air Temperature, deg. fahr
Carbureter Air Temperature, deg cent

FIG. 11—COMPARISON OF THE AMOUNTS OF *B* AND *D* FUEL CONSUMED AT A SPEED OF 1200 R.P.M. AND FULL THROTTLE

dicate greater fuel-consumption with *D* than with *B* fuel. This difference varies from about 10 per cent at —5 deg. cent. (23 deg. fahr.) to practically zero per cent at 65 deg. cent. (149 deg. fahr.). Further investigation of this condition of operation seems desirable as it appears to be of importance in the normal operation of the car under winter starting conditions. The results seem to show that with this engine and under conditions of low speed and temperature, more of *D* than of *B* fuel is required to give a maximum-power mixture or to operate at all. If the carbureter were set for constant-speed operation under these conditions, the consumption of the less-volatile fuel probably would be greater under other conditions also. If, on the other hand, the carbu-

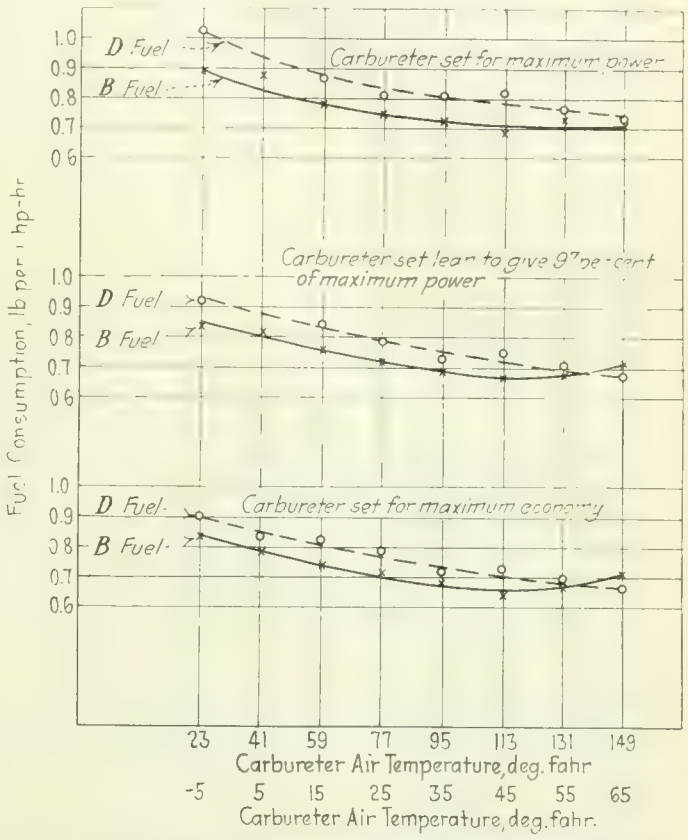

D Fuel
B Fuel
Carbureter set for maximum power
Carbureter set lean to give 97 per cent of maximum power
Carbureter set for maximum economy
Fuel Consumption, lb per i hp-hr
Carbureter Air Temperature, deg. fahr
Carbureter Air Temperature, deg. fahr.

FIG. 12—COMPARISON OF THE AMOUNTS OF *B* AND *D* FUEL CONSUMED AT A SPEED OF 500 R.P.M. AND PART THROTTLE

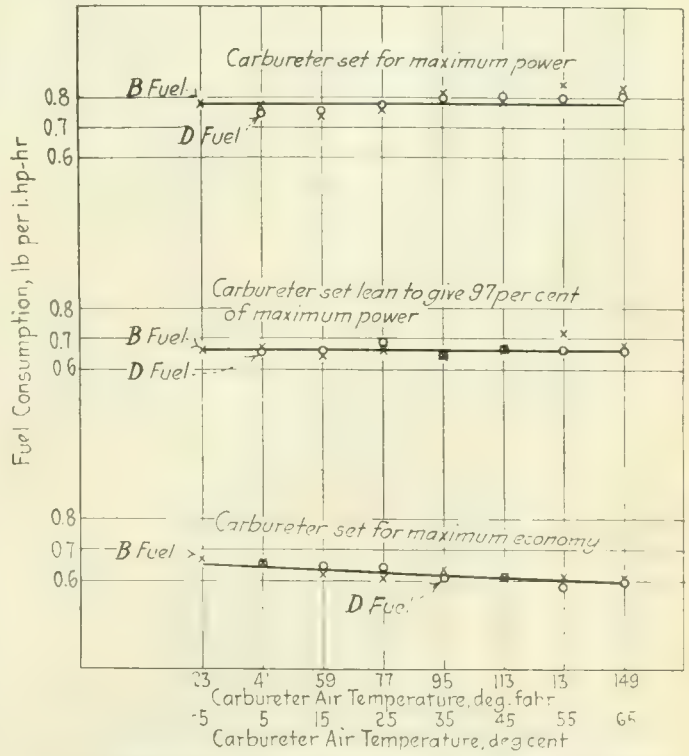
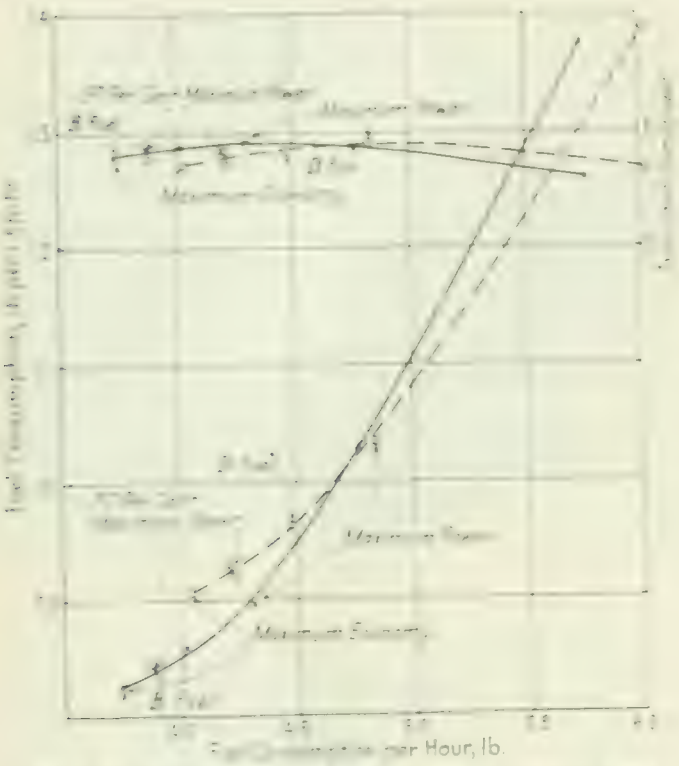
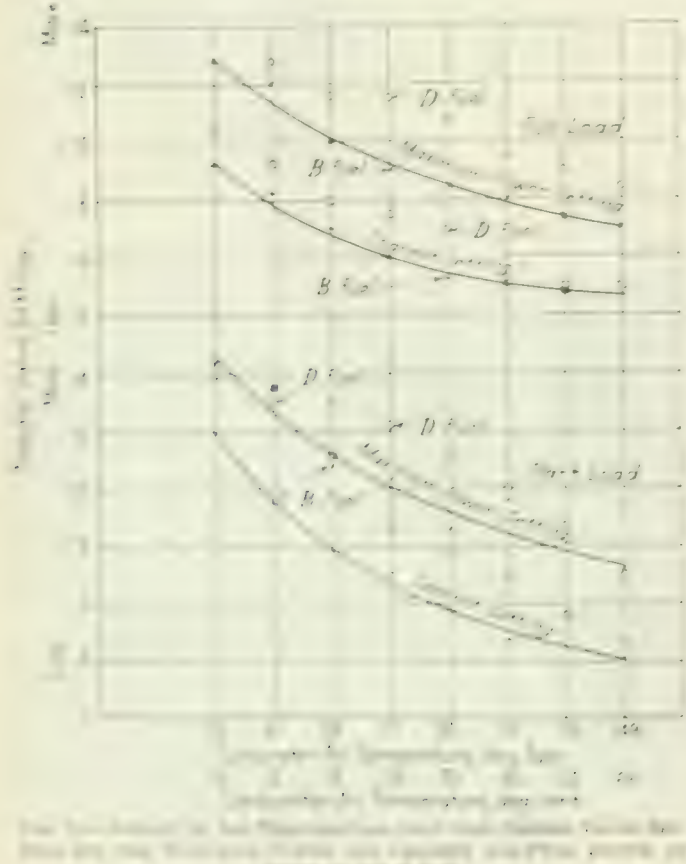

Carbureter set for maximum power
B Fuel
D Fuel
Carbureter set lean to give 97 per cent of maximum power
Carbureter set for maximum economy
Fuel Consumption, lb per i.hp-hr
Carbureter Air Temperature, deg. fahr
Carbureter Air Temperature, deg cent

FIG. 13—COMPARISON OF THE AMOUNTS OF *B* AND *D* FUEL CONSUMED AT A SPEED OF 800 R.P.M. AND PART THROTTLE



were altered to meet changing conditions, especially those of temperature, differences in the fuel consumption probably would be limited to those periods of operation when the conditions already mentioned



The results indicate a decrease in the fuel-consumption with a rise in the temperature, and this effect is perhaps more marked in the case of *D* fuel as evidenced by the greater downward slope of the curves for *D* fuel. The temperature effect is most pronounced at that speed and load at which the difference between *B* and *D* fuel appeared.

The reasons for this change in the consumption with the temperature are probably also the reasons for the difference in the economy as between two fuels of widely different volatilities. If all cylinders of an engine could be filled with identically equal mixtures of gasoline vapor and air at the time of ignition, regardless of air temperature and the volatility of the fuel, there is little reason to believe that there would be an appreciable difference in fuel consumption between fuels or temperatures within the ranges under consideration. However, at the temperatures and with the fuels used in this test, the mixtures received by the cylinders may not be similar and the fuel may not always be vaporized entirely by the time of ignition.

That the mixtures received by the cylinders may not be the same, either between themselves or from cycle to cycle, is due to the fact that part of the fuel passes through the intake system as liquid and most manifolds do not distribute liquid as uniformly as gas. The higher the air temperature is and the more volatile the fuel is, the less will be the amount of liquid to be distributed and the more uniform will be the distribution. It should be realized, however, that when the conditions are such that practically all of either of two fuels passes through the manifold as liquid, no difference in distribution would be expected as between the fuels, for a manifold should distribute the liquid of the one no less uniformly than the liquid of the other.

The less the amount of liquid fuel entering the cylinder, the greater will be the likelihood that all of it will be vaporized in time to be utilized fully. It is recognized that for normal operation temperatures any of the fuels with which we have to deal can be fully utilized in any single cylinder. It is seen then that, with cold temperatures and with fuels of low volatility, an excess of fuel must be supplied so that the mixtures of fuel vapor and air in each cylinder at the time of ignition shall be rich enough to fire. These tests indicate that the difference in volatility between *B* and *D* fuels, although sufficient to affect appreciably their estimated possible production, is not great enough to result in a very marked difference in their action in this engine when operating at constant speed and load.

Fig. 14 is included merely to illustrate the method of obtaining the points plotted in Figs. 9 to 13. The curves shown in Fig. 14 are for *B* and *D* fuels, with the engine conditions indicated. The fuel consumption at maximum power is obtained by selecting the highest point of the power curve, and then taking the corresponding consumption-value from the fuel-consumption curve vertically beneath. Since the particular consumption at which maximum power is obtained is often difficult to select from a flat power-curve, it sometimes is desirable to use the consumption corresponding to a certain percentage of maximum power to the lean side of the maximum point. The maximum-power value is obtained easily, even though the consumption at which it is obtained is indefinite. The maximum-economy values are, naturally the lowest points of the fuel-consumption curves in the lower part of Fig. 14. The curves in Fig. 14 are the basis of points plotted on Fig. 12 for —5 deg. cent. (23 deg. fahr.).

CONCLUSIONS OF CONSTANT-SPEED FUEL TESTS

The results of the constant-speed tests with the Car-*Z* engine do not show large differences in fuel consumption as between the *B* and *D* fuels. The greatest difference observed was much less than the difference between the estimated possible productions of the two fuels.

It is concluded that the difference in volatility that exists between *B* and *D* fuels is not so large as to produce considerable differences in fuel consumption in existing automobiles, at least under conditions of constant speed and load. Whether or not richer mixtures would need to be used with the less-volatile fuel to obtain equal ease of starting and acceleration is yet to be determined.

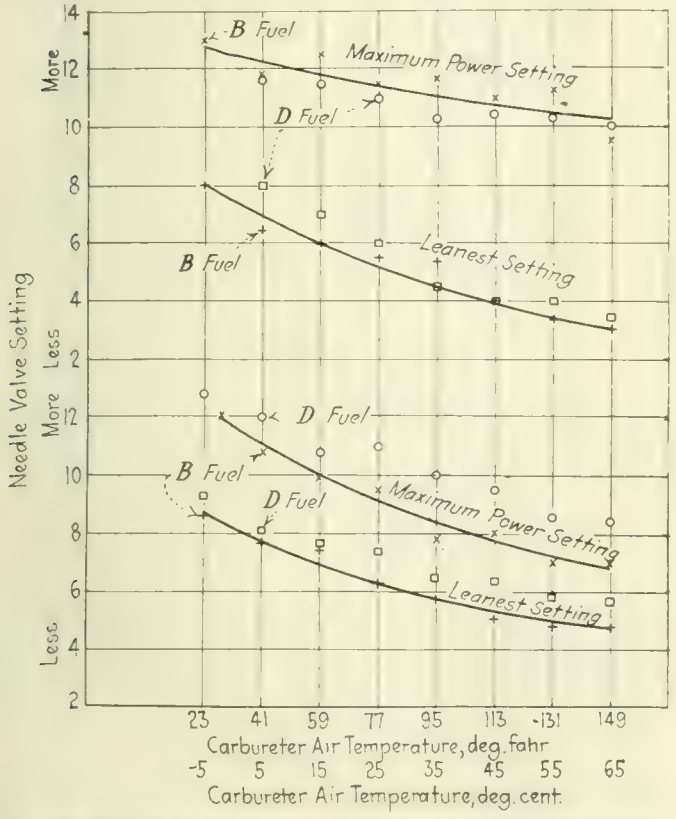


FIG. 16—EFFECT OF AIR TEMPERATURE UPON THE NEEDLE-VALVE SETTING FOR THE MAXIMUM-POWER AND LEANEST AIR-FUEL RATIOS AT A SPEED OF 800 R.P.M.

It should be remembered in this connection that the accelerations involved in the Speedway tests were accomplished satisfactorily with the less-volatile oils.

AIR-TEMPERATURE AND FUEL-VISCOSITY EFFECTS

Regarding the effect of air temperature and fuel viscosity upon carbureter adjustment, an interesting sidelight on the subject of carbureter adjustment is given in Figs. 15 to 17. This may explain many apparent inconsistencies that appear in the fuel tests. These curves were plotted from the data of the fuel-consumption tests just described. They show the needle-valve settings that were made by the operator to obtain maximum power from the engine at each particular carbureter-air temperature. The leanest settings at which the engine would operate regularly are given also. The "needle-valve settings" refer to the position of a dial connected to the needle-valve of the carbureter. The circumference of this dial is divided into 18 parts which are numbered and referred to. The large changes in the needle-valve setting that it was necessary to make to obtain maximum-power

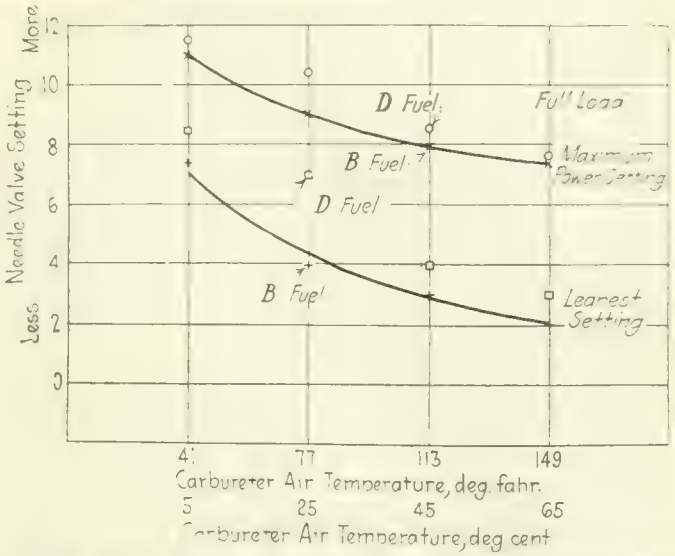


FIG. 17—EFFECT OF AIR TEMPERATURE UPON THE NEEDLE-VALVE SETTING FOR THE MAXIMUM-POWER AND LEANEST AIR-FUEL RATIOS AT A SPEED OF 1200 R.P.M.

mixtures at different temperatures explain how great an influence the temperatures of the gasoline and the air may have upon the performance of an engine and a carbureter of this type when the carbureter is not altered to meet each change in the temperature. For example, if the carbureter were adjusted for the maximum power with the engine operating at a 65-deg. cent. (149-deg. fahr.) air-temperature, at 500 r.p.m. and full throttle, shown in Fig. 15, and the air temperature subsequently should fall below 13 deg. cent. (55.4 deg. fahr.), the mixture would be so lean that the engine would cease to run. Similarly, if the carbureter were adjusted for the maximum power at a low air-temperature, the mixture would be entirely too rich at the higher air-temperatures. The above indicates the difficulty of obtaining uniformly satisfactory operation without (*a*) varying the carbureter setting to take care of changes in temperature conditions, or (*b*) providing some means of controlling the temperature to agree with a given carbureter-setting. This difficulty is present to almost the same degree with

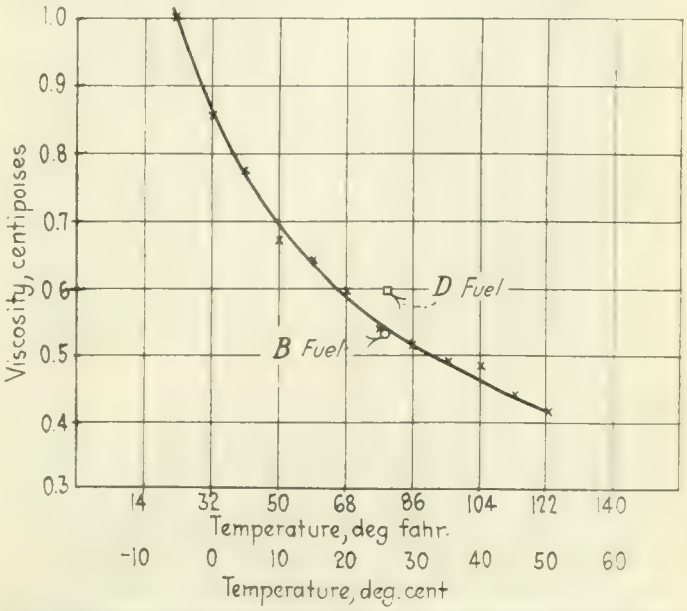
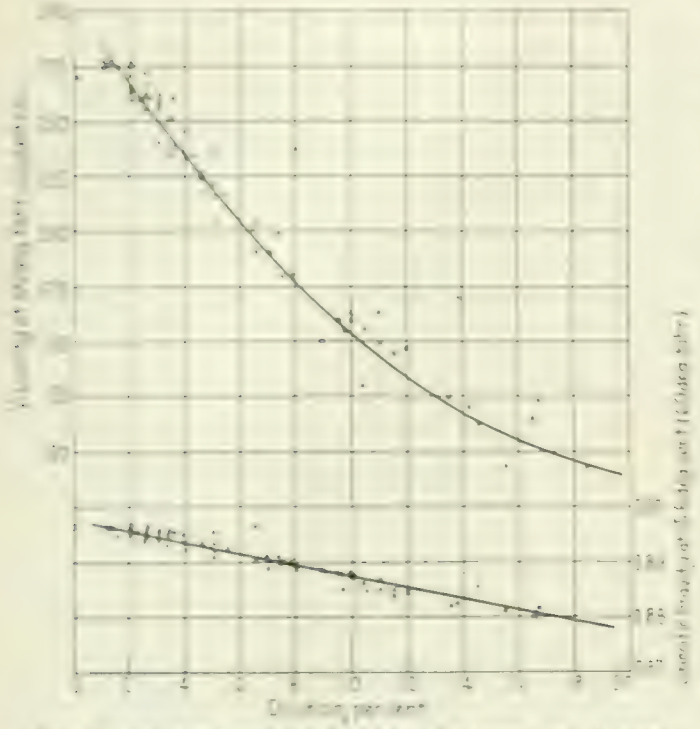


FIG. 18—EFFECT OF TEMPERATURE UPON THE VISCOSITY OF A COMMERCIAL GASOLINE HAVING A SPECIFIC GRAVITY OF 0.743 AT 25 DEG. CENT. (78.8 DEG. FAHR.)



VISCOSITY OF THE [illegible]

and of the fuels used in these tests but is undoubtedly less with carbureters in which fuel viscosity has but little effect.

The reasons, other than difference in efficiency of fuel utilization, why the needle-valve opening must be increased to give a maximum-power mixture when the air temperature is decreased, seem to be as follows:

(1) The lower the *fuel temperature* is, the greater will be its viscosity; and the greater the viscosity is, the less the flow will be, other conditions remaining the same. To maintain a constant air-fuel ratio, this effect must be compensated for by an increase in needle-valve opening. The increase in fuel density with a decrease in the temperature tends to compensate for this viscosity effect, but, with gasoline, the viscosity changes much more rapidly with temperature than does the density. Fig. 18 shows the very considerable effect of temperature upon the viscosity of a commercial gasoline, and also gives the viscosities of *B* and *D* fuels at a single temperature.

(2) Even if the viscosity of the fuel were unaffected by temperature, a decrease in air temperature would bring about a leaner mixture because the lower the air temperature is, the less will be the pressure difference inducing fuel flow which will be produced by a given weight of air flowing through the carburetor. The air flow remaining unchanged and the fuel flow decreasing, a leaner air-fuel ratio will result if the needle-valve opening is not increased.

In Figs. 13 to 17 it will be noticed that the points for *D* fuel almost always fall above those for *B* fuel, indicating that a greater needle-valve opening is necessary with *D* fuel than with *B* fuel. Since there was no consistent difference in maximum power between the two fuels in these tests, other than as [illegible] to fuel flow, it follows that the flow of *D* fuel at *B* fuel throat through the carburetor jet and hence the greater needle-valve opening was necessary merely because of the greater viscosity of the *D* fuel. This checks and explains what was found in the summer road-tests; namely, if the carbureter were set for the maximum power with each fuel, the setting for *D* fuel appeared to be richer but no great difference in the number of miles per gallon resulted because there was little change in the fuel flow. If, on the other hand, *D* fuel were used when the carbureter was set for the maximum power with *B* fuel, more miles per gallon but otherwise inferior performance was obtained with the *D* fuel.

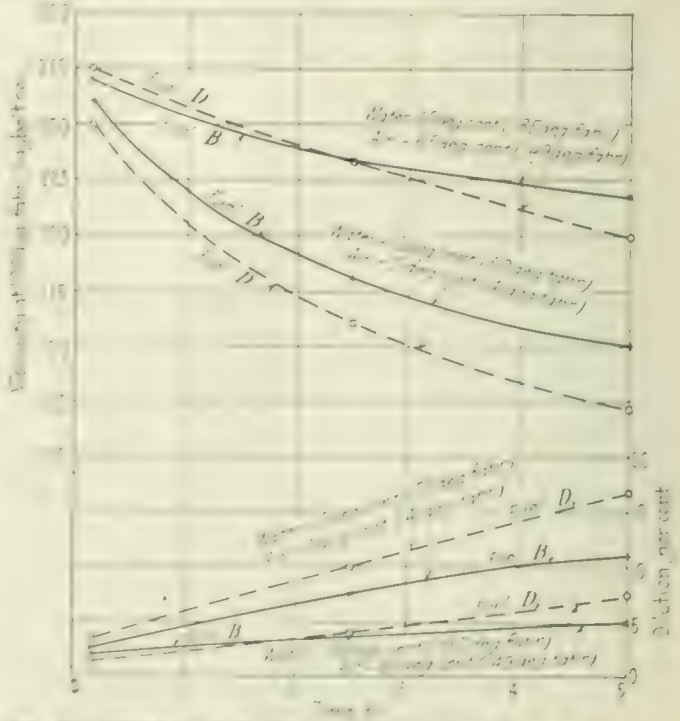
Two tendencies of significance are suggested by a consideration of the viscosity effect in carbureters of this type, as follows:

(1) When drivers observe a difference in fuels as regards flexibility, power and acceleration, these differences may be due to the fact that a leaner mixture is obtained with the less-volatile and more viscous fuel at a given carbureter-setting as well as to a difference in vaporization or distribution. In fact, the fuel consumption may be as low or lower under these conditions.

(2) Variations in the distillation characteristics of the gasolines now sold may indicate corresponding variations in viscosity, which would have the effect described in (1). That the distillation characteristics of motor gasoline do vary appreciably is indicated by the semi-annual motor gasoline surveys by the Bureau of Mines. An examination of the data given in the above-mentioned report will show that gasoline is much more uniform than it was formerly, but that the variation throughout the country is still appreciable. If carbureter adjustments are made so as to give satisfactory performance with the more-viscous fuels, then the less-viscous fuels will be used in over-rich and wasteful mixtures. Therefore, fuel uniformity as well as fuel volatility is important insofar as economy is concerned.

CRANKCASE-DILUTION TESTS

By crankcase dilution is meant the addition of fuel to the lubricating oil. It is believed generally that the dilution obtained with present fuels and engines is greater than was obtained some years ago, and that the



THE EFFECT OF FUEL VOLATILITY UPON THE RATE OF DILUTION

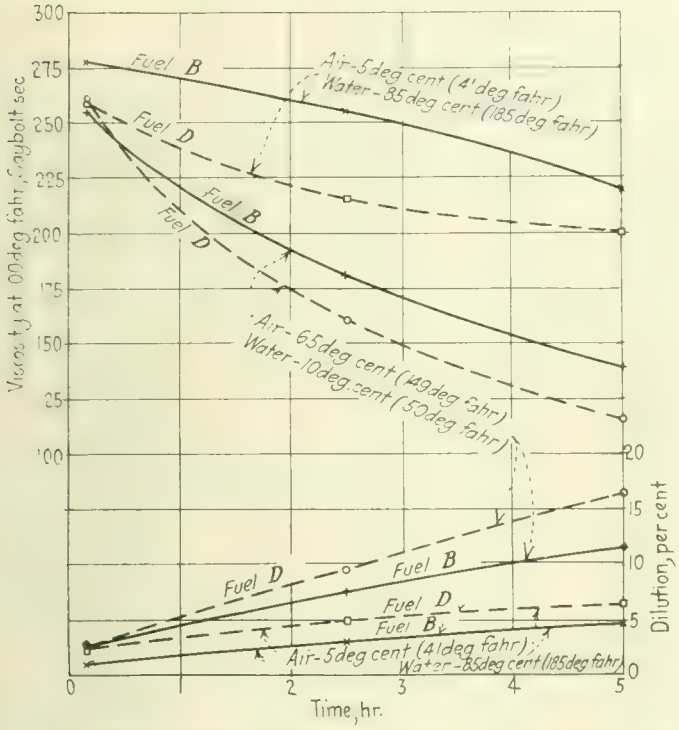


FIG. 21—ANOTHER SET OF CURVES SHOWING THE EFFECT OF FUEL VOLATILITY UPON THE RATE OF DILUTION

decrease in fuel volatility which has taken place is responsible chiefly for the increased dilution. Therefore, the effect of a further decrease in fuel volatility upon the rate of dilution was considered to be an important part of this investigation.

The one well recognized effect of dilution is to diminish the viscosity of the lubricant greatly. Whether it has any other important effect is not definitely known. The viscosity still is regarded as the most important measurable property that an oil possesses and is a fairly reliable indication of the ability of an oil to maintain its lubricating film under all conditions of temperature, pressure and speed. It is desirable to use the least viscous oil that will keep the metal surfaces apart consistently. If the viscosity is less than this, wear of the engine parts will occur during the moments of heaviest load and highest temperature. The less the viscosity, the greater will be the frequency and the duration of these periods of wear. It also is possible that a critical condition of the oil-seal between the piston and the cylinder may exist; that is, when the viscosity of the lubricant falls below a particular value, "blowing-by" and rapid wear may occur. If, on the other hand, an oil of unnecessarily high viscosity is used, the friction losses will be large and the load on the starting motor excessive, because engine friction is largely the resistance to shear of the oil-film on the cylinder-walls and in the bearings, especially the former. It is evident, then, that a rapid rate of crankcase dilution produces a very unstable lubrication condition. If the oil is of correct viscosity at the outset, it will soon be too thin to prevent wear, but if a more viscous oil is used to postpone this condition, a high initial-friction loss is the consequence. The car user is subjected to the nuisance and the expense incident to draining and refilling the crankcase frequently and is often uncertain as to whether he has estimated the rate of dilution correctly.

The summer road-tests for oil dilution indicated a distinctly greater rate of dilution with the less-volatile fuels. The laboratory-test program with the Car-*Z* engine included tests intended not only to compare the rates of dilution obtained with the test fuels but also to determine what conditions of operation have the greatest influence upon the rate of dilution.

DILUTION-TEST PROCEDURE

The procedure adopted for the dilution tests was as follows: The engine was warmed-up, using old oil. During this period, the desired carbureter adjustment, to give as nearly as possible the same mixture-ratio with each fuel, circulating-water temperature and carbureter-air temperatures were secured. The engine was then stopped and the oil drained from the crankcase. Then, 2 qt. of new oil was poured into the crankcase, the engine was motored over, the oil was drained again and a weighed quantity of new oil was poured in. A weighed gasoline-tank was then connected to the carbureter, and the engine was started. The first sample of oil was drawn from the crankcase 10 min. thereafter, without stopping the engine. This sample was considered necessary because the oil in the crankcase at the start of the run was not entirely free from dilution, despite the foregoing procedure. Thereafter, only one more oil-sample was taken until the end of the run, usually a period of 5 hr., so as not to reduce the quantity of lubricant in the crankcase materially. Every effort was made to keep the temperature and the other engine conditions constant. At the end of the run, the crankcase was drained and the contents were weighed; the gasoline tank was weighed also.

All oil-samples were tested as to specific gravity, viscosity and "per cent dilution." The viscosity was obtained with a Saybolt viscosimeter at 37.8 deg. cent. (100 deg. fahr.). The "per cent dilution" was obtained by the following method: A small quantity, 100 cc. of the oil sample, was placed in an Engler distillation flask and heated to the boiling temperature of the new oil, which is 305 deg. cent. (581 deg. fahr.). The products of distillation were condensed and collected in a graduate. The number of cubic centimeters collected in the graduate was called the "per cent dilution." The "per cent dilution" and the Saybolt viscosity at 37.8 deg. cent. (100

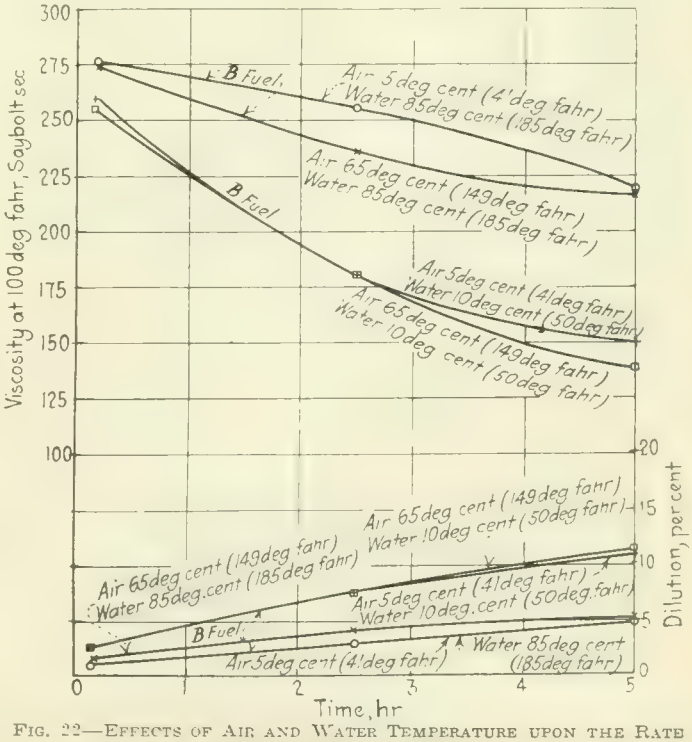

Viscosity at 100 deg fahr, Saybolt sec
Dilution, per cent
Time, hr
B Fuel
Air 5deg cent (41deg fahr)
Water 85deg cent (185deg fahr)
Air 65deg cent (149deg fahr)
Water 85deg cent (185deg fahr)
Air 5deg cent (41deg fahr)
Water 10deg cent (50deg fahr)
Air 65deg cent (149deg fahr)
Water 10deg cent (50deg fahr)
Air 65deg cent (149deg fahr)
Water 10deg cent (50deg fahr)
Air 65deg cent (149deg fahr)
Water 85deg cent (185deg fahr)
Air 5deg cent (41deg fahr)
Water 10deg cent (50deg fahr)
Air 5deg cent (41deg fahr)
Water 85deg cent (185deg fahr)

FIG. 22—EFFECTS OF AIR AND WATER TEMPERATURE UPON THE RATE OF DILUTION WITH *B* FUEL

[illegible] tabl[illegible] of such [illegible] taken in these tests are plotted in Fig. 19. Although there may be some difference of opinion as regards the accuracy of the methods used in determining crankcase dilution, all the results were determined by the same methods with the same oil and are therefore at least comparative.

CRANKCASE-DILUTION TEST RESULTS

Some preliminary runs were made at 600 r.p.m. at full throttle and at part throttle, with *A* and *D* fuels and with normal temperatures. A more comprehensive program was then followed, of which the runs shown in Table 4 have been completed.

The results of the crankcase-dilution runs are given in Table 5 and in Figs. 20 to 27. It should be realized that

TABLE 4.—CRANKCASE-DILUTION TESTS

Fuel	Test No.	Load	Speed, r.p.m.	Air Temp. Entering Carbureter, Deg. Fahr.	Water Temp. Leaving Engine, Deg. Fahr.	Duration of Test, Hr.
A	[illegible]	[illegible]	[illegible]	150	150	5
D	[illegible]	[illegible]	[illegible]	150	150	5
B	[illegible]	[illegible]	[illegible]	40	150	5
A	[illegible]	[illegible]	[illegible]	40	150	5
D	[illegible]	[illegible]	[illegible]	40	150	5
B	[illegible]	[illegible]	[illegible]	40	150	5
A	[illegible]	[illegible]	[illegible]	40	150	5
D	[illegible]	[illegible]	[illegible]	40	150	5

[illegible] [illegible] of Initial Fuel in Sump [illegible]

Test No.	Test Fuel	Initial Sump Charge
[illegible]	100	290
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	581	

[illegible] results, obtained with but one type of engine and one oil under certain fixed conditions, are not directly applicable to all cases, but that they do indicate general [illegible]

[illegible] Effect of Mixture Ratio upon the Rate of Dilution with *D* Fuel

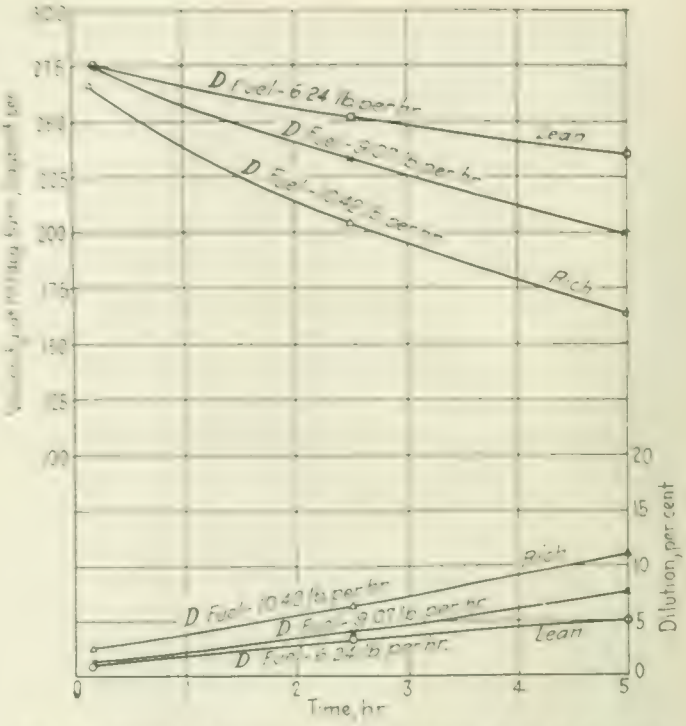


Fig. 21.—Effect of Mixture Ratio upon the Rate of Dilution with *D* Fuel

In Figs. 20 to 26, the results of the viscosity and the "per cent dilution" tests of the oil samples taken during the runs are shown. These results are plotted against the time at which the samples were drawn from the crankcase. Figs. 20 and 21 show that a greater rate of dilution was obtained with the less-volatile *D* fuel than with *B* fuel, under each of four combinations of air and water temperature. This difference in rate of dilution is evidenced not only by the viscosity and the "per cent dilution" curves in Figs. 20 and 21, but also by the changes in the amount of lubricant in the crankcase given in the last column of Table 5. The apparent oil-consumption is almost always less with *D* fuel, indicating a greater addition of fuel to the lubricant.

Figs 22 and 23 show the relative effects of carbureter-air and circulating-water temperatures upon the rate of dilution. It is evident that, with this engine and within the given ranges of temperature, the circulating-water temperature had a much greater influence upon the rate of dilution than had the carbureter-air temperature. This result is supported by no less than four runs at each of the four combinations of air and water temperature as shown in Table 4. It should be noted in this connection that the intake-manifold on this engine is cast separately from the cylinder-block and is not hot-spotted; therefore the carbureter-air temperature does determine the charge temperature to a large extent. It is natural to suppose that the air temperature would determine how much or how little of the fuel entered the cylinder in the liquid state and, hence, how great or how little the rate of dilution would be. Also, given a condition where part of the fuel does enter the cylinder as liquid, the higher the piston and the wall temperatures, the greater would be the likelihood of complete vaporization and a low rate of dilution. It has been shown that jacket-water temperatures may have a very considerable influence on piston and wall temperatures, in the piston-temperature measurements given in a paper entitled Aluminum Pistons, by Jehle and Jardine[1].

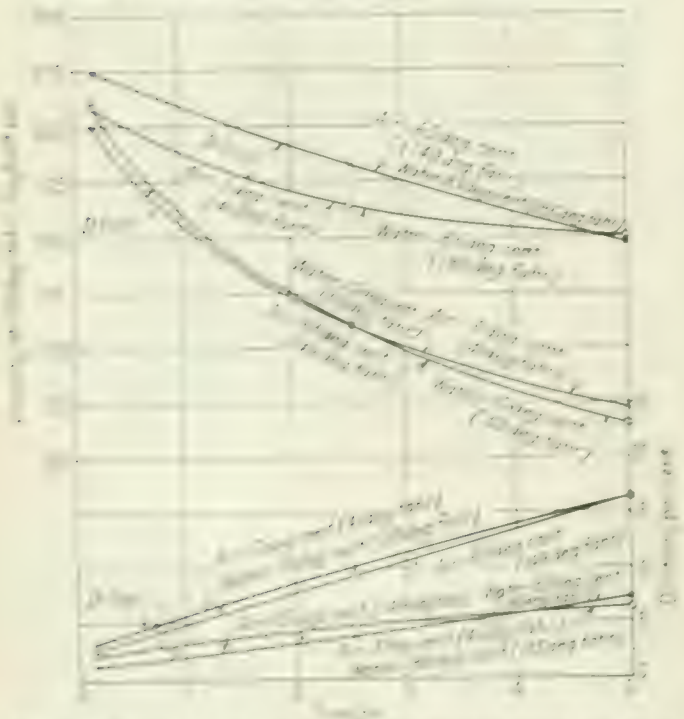


Fig. [illegible] [illegible] and Water Temperature upon the Rate of Dilution with *D* Fuel

TABLE 5—DETAILS OF RUNS

No.	Fuel	Per Hr.	Viscosity in Saybolt Sec. of Samples Taken at 10 Min.	2.5 Hr.	5 Hr.	Percentage of Dilution of Samples Taken at 10 Min.	2.5 Hr.	5 Hr.	Change in Weight of Crankcase Contents, Lb.
600 r.p.m. Full Load, Carbureter-Air Temperature, 65 Deg. Cent. (149 Deg. Fahr.); Outlet-Water Temperature, 85 Deg. Cent. (185 Deg. Fahr.)									
1	*B*	8.90	275	234	217	1.5	4.3	5.5	—0.3
2	*D*	9.07	276	233	198	1.3	4.0	7.4	—0.2
3	*B*	6.06	276	260	245	2.0	3.0	3.9	—0.7
4	*D*	6.24	276	251	235	1.2	3.4	5.0	—0.7
5	*B*	10.70	274	203[a]	227[a]	2.0	...	8.5	+0.5
6	*D*	10.42	267	203	163	2.5	6.5	11.0	+0.6
600 r.p.m. Full Load, Carbureter-Air Temperature, 5 Deg. Cent. (41 Deg. Fahr.); Outlet-Water Temperature, 10 Deg. Cent. (50 Deg. Fahr.)									
7	*B*	10.40	261	180	149	2.5	7.8	11.0	+0.7
8	*D*	10.55	251	161	122	3.3	10.0	16.7	+1.2
9	*B*	9.30	261	191	155	2.6	7.0	10.5	+0.7
10	*D*	9.31	272	170	129	2.5	13.8	22.0	+0.8
11	*B*	12.69	259	150	113	3.0	8.9	14.5	+1.2
12	*D*	11.95	260[a]	129	93	3.5	10.4	15.5	+1.6
600 r.p.m. Full Load, Carbureter-Air Temperature, 65 Deg. Cent. (149 Deg. Fahr.); Outlet-Water Temperature, 10 Deg. Cent. (50 Deg. Fahr.)									
13	*B*	9.96	255	179	138	2.5	7.5	11.5	+0.9
14	*D*	10.16	262	160	115	2.5	9.5	16.5	+1.1
15	*B*	8.44	259	191	162	2.1	6.5	9.9	+0.7
16	*D*	8.50	263	237	147	2.0	8.0	12.0	+0.7
17	*B*	12.00	265	155	124	2.0	9.7	13.5	+0.9
18	*D*	11.61	257	144	...	3.0	11.5	.....	.....
600 r.p.m. Full Load, Carbureter-Air Temperature, 5 Deg. Cent. (41 Deg. Fahr.); Outlet-Water Temperature, 85 Deg. Cent. (185 Deg. Fahr.)									
19	*B*	9.33	277	255	218	1.0	3.0	4.7	—0.0
20	*D*	9.41	259	216	200	2.3	5.0	6.4	+0.2
21	*B*	8.17	270	240	225	2.0	3.0	4.5	+0.1
22	*B*	10.75	270	238	221	0.1	3.5	5.0	—0.2
600 r.p.m. Part Load, Carbureter-Air Temperature, 5 Deg. Cent. (41 Deg. Fahr.); Outlet-Water Temperature, 10 Deg. Cent. (50 Deg. Fahr.)									
23	*B*	4.48	274	235	220	2.0	3.3	5.0	+0.3
600 r.p.m. Motoring, Carbureter-Air Temperature, 5 Deg. Cent. (41 Deg. Fahr.); Outlet-Water Temperature, 25 Deg. Cent. (77 Deg. Fahr.)									
24	*B*	5.34	203	77[b]	...	5.0	23.0[b]	...	+2.4
600 r.p.m. Full Load, 15 Hr., Carbureter-Air Temperature, 5 Deg. Cent. (41 Deg. Fahr.); Outlet-Water Temperature, 10 Deg. Cent. (50 Deg. Fahr.)									
25	*B*	10.17	262	...	170	1.5	...	9.3	+0.6
25	*B*	....	...	...	121[c]	..	...	14.2[c]	....
25	*B*	....	...	...	93[d]	..	...	18.4[d]	....

[a] Sample contained water.
[b] Sample taken at 2 hr.
[c] Sample taken at 10 hr.
[d] Sample taken at 15 hr.

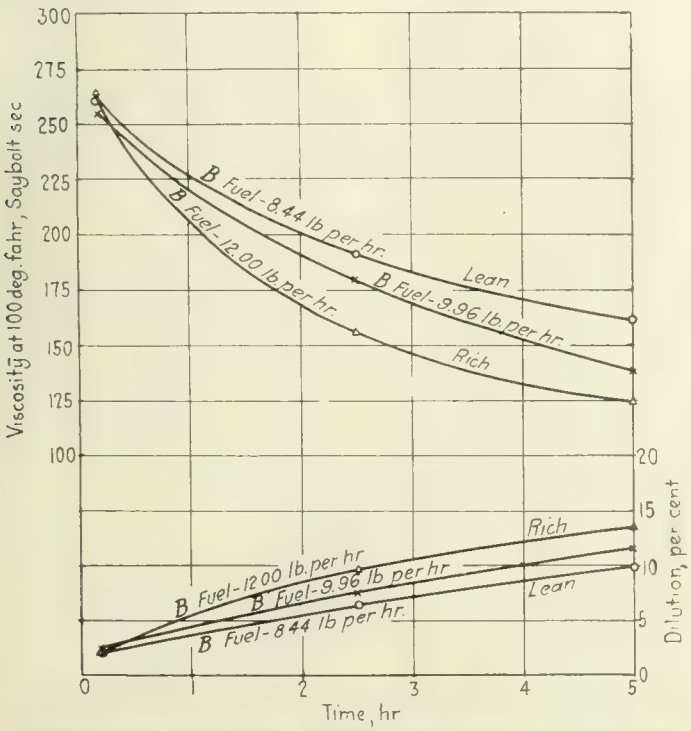


FIG. 25—EFFECT OF MIXTURE-RATIO UPON THE RATE OF DILUTION WITH *B* FUEL

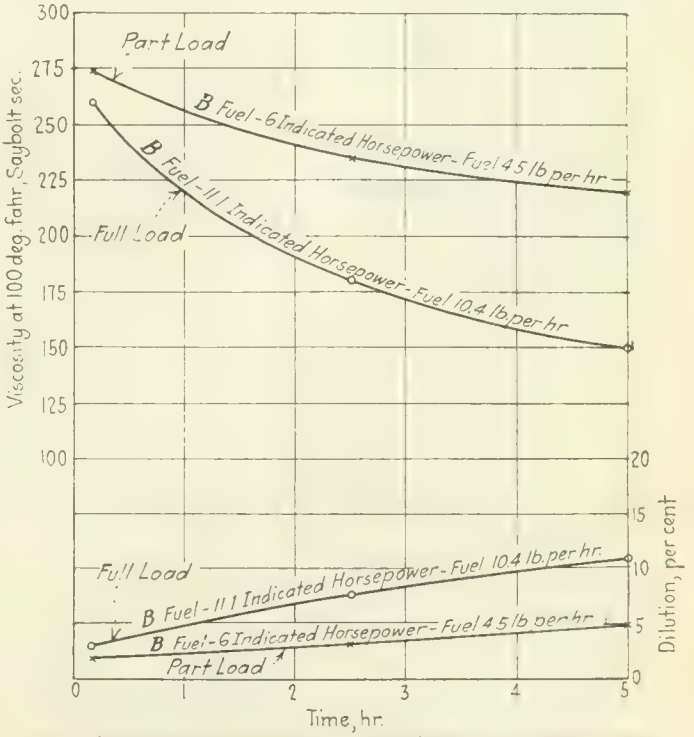
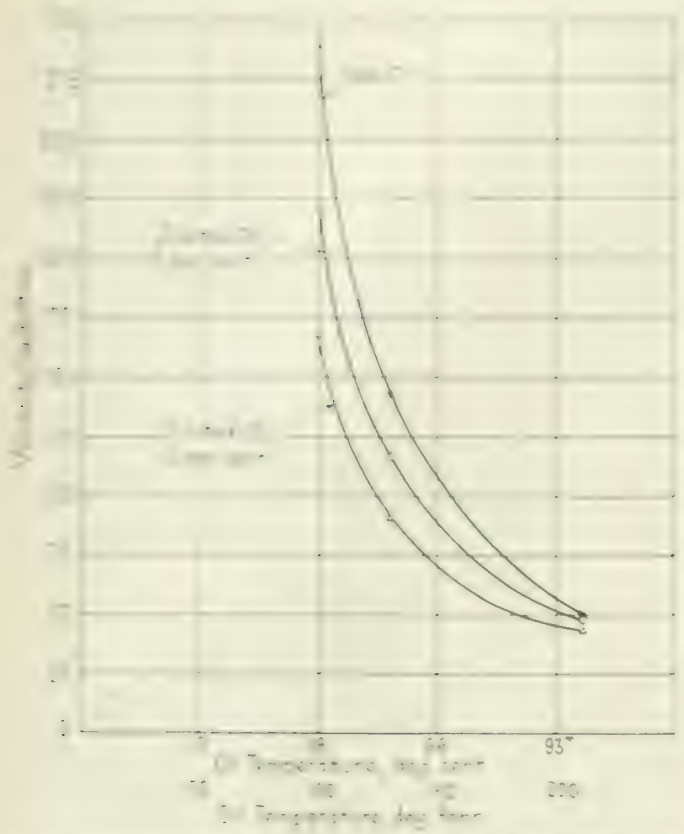
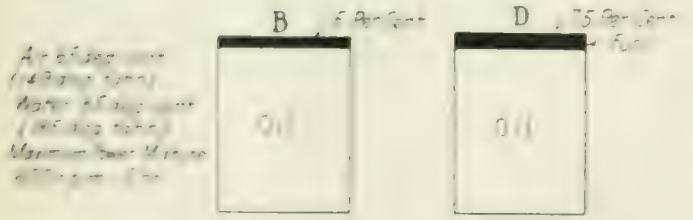
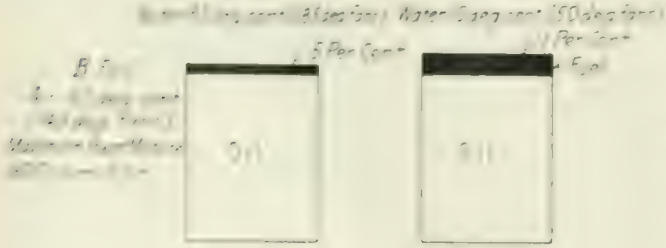
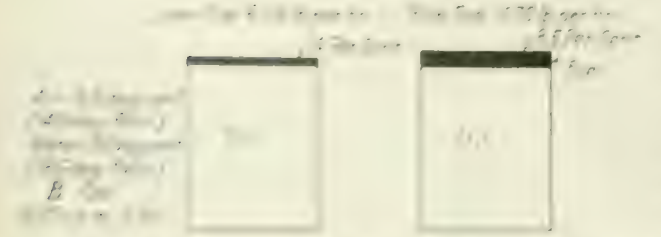

Viscosity at 100 deg. fahr, Saybolt sec.
Dilution, per cent
Time, hr.
Part Load
B Fuel-6 Indicated Horsepower-Fuel 4.5 lb per hr
B Fuel-11.1 Indicated Horsepower-Fuel 10.4 lb per hr
Full Load
Full Load
B Fuel-11.1 Indicated Horsepower-Fuel 10.4 lb per hr.
B Fuel-6 Indicated Horsepower-Fuel 4.5 lb per hr.
Part Load

FIG. 26—EFFECT OF LOAD UPON THE RATE OF DILUTION WITH *B* FUEL









A probable explanation of why the water temperature is the predominating influence is as follows: The highest carbureter-air temperature used, 65 deg. cent. (149 deg. fahr.), probably is not high enough to vaporize all of either fuel, even if there were sufficient time. There is always liquid fuel entering the cylinders at both high and low air-temperatures but, of course, there is a greater proportion of liquid in the latter case, the increase being in the more-volatile portions. The more-volatile portions of the liquid vaporize readily enough in the cylinder and only the less-volatile portions contribute to the dilution. Therefore the greater amount of the lighter constituents entering the cylinders as liquid at the lower air-temperatures makes little difference. The least volatile fractions are not vaporized at the time of entrance with either of the carbureter-air temperatures considered and, hence, become the determining factor. The rate of dilution depends therefore upon the ability of the piston and the cylinder wall to vaporize the heaviest portion of the fuel, which is a function of the jacket-water temperature.

Figs. 24 and 25 serve to illustrate the effect of mixture-ratio upon dilution. It will be seen that the richer the mixture is, the greater the dilution will be, and that the effect is approximately in proportion to the rate of fuel consumption.

The results of the 15-hr. dilution test given in Table 5 show that the viscosity decreases rapidly throughout the test. This seems to indicate that, with low temperature-conditions, dilution does not reach equilibrium in a test of this length. The Saybolt viscosity of the lubricant at 37.8 deg. cent. (100 deg. fahr.) was reduced to less than one-third that of the unused oil. A contemplated 15-hr. test with higher air and water-temperatures may show a considerably different result. At the higher oil-temperatures such as will be obtained, the diluent may be distilled from the lubricant at such a rate as ultimately to equal the rate at which the fuel was being added and equilibrium ensue. The relative ability of two fuels to reach equilibrium while the oil still has sufficient lubricating qualities may be an important consideration in any oil-consumption estimates as between two fuels. The rate of dilution under starting conditions was found to be several times as great as when operating.

Fig. 26, a comparison of the dilution at one-half of the indicated load with that at full load, shows that the dilution at full load was the greater and apparently in proportion to the indicated load or the fuel consumption. It should be realized, however, that the same air and water-temperatures were maintained at part as at full throttle, a condition that rarely exists for long in the usual operation of automobile engines.

Fig. 27 is included to show the effect of the temperature upon the viscosities of diluted and of undiluted oil. The curves show that a small increase in temperature may reduce the viscosity of the oil fully as far as a considerable amount of dilution. The temperature of the lubricant separating the piston and the cylinder may vary from that of the atmosphere to at least 100 deg. cent. (212 deg. fahr.). This is an illustration of the importance of choosing a lubricant for the temperature condition best adapted to the engine under consideration and then striving to maintain the lubricant and the temperature constant. Fig. 28 illustrates the relative magnitude of the effect of fuel volatility, circulating-water temperature and mixture-ratio upon dilution.

CONCLUSIONS DRAWN FROM CRANKCASE-DILUTION TESTS

In conclusion, the rate of crankcase dilution is greater with the less-volatile fuels under all conditions of test.

In that these conditions cover a wide variation of mixture-ratio and of air and water-temperature, it is reasonable to suppose that such would be the case during a large majority of the time of operation of existing cars. That many cars have engines differing from the test engine in design may alter the magnitude of the differences but not the fact of their existence. In general, it has been found that the circulating-water temperature has the greatest single influence upon the rate of dilution, and that the mixture-ratio has a considerable effect.

Acceleration and Starting Tests

The acceleration and starting tests are now being run with the Car-*Z* engine set-up. It is hoped that the methods used will detect any significant differences which may exist.

MOTOR-TRANSPORT ACTIVITIES OF THE OFFICERS' RESERVE CORPS

As the National Defense Act forms our military establishment into a small standing army and a large reserve, it is desirable that those engaged in the automotive industry interest themselves as citizens and tax-payers in the development of this Reserve. The mistakes made during the war are well known to those who served in the ranks, as well as to those who managed the many different organizations that were directly or indirectly engaged in furnishing munitions of war, whether it was cotton for the tents, steel for the ordnance or automotive parts for transportation, and to prevent, if possible, and in any case reduce the number of the mistakes that occurred in the past, officers in charge of the various Corps Areas are making every effort to interest men who would, in time of war, be called into active service, especially technical and mechanical men.

It is recognized that able-bodied men will be drafted into the service with or without their consent if the emergency requires it. The problem is to anticipate the demand. A bulletin describing the regulations for the Officers' Reserve Corps may be obtained from the Army. One having determined which branch of the service he wishes to enter, it is necessary to have the application papers forwarded to the Commanding Officers of a Corps Area for a commission in the Corps. Each organized reserve unit will be localized, with all its officers residing in its own territory. The enlisted personnel will be assigned to units localized in or near their places of residence. Provision will be made for transferring the officers and the enlisted men, upon any change of residence, to similar units in their new homes.

As the reserve will be distinctly a war force and will not be called to the colors except in such an emergency, it will attract a class of citizens who do not feel inclined or are unable to undertake the obligations assumed by members of the National Guard. Moreover, the reserve will be maintained as a skeletonized force and will not compete with the National Guard. The policy of the General Staff contemplates a well-balanced force officered by regular, National Guard and organized reserve officers and capable of expansion to any required size. The expansion of the limit of strength will take place through voluntary enlistment or draft as emergency may demand. Each Corps Area will contain troops from the regular army, the National Guard and the organized reserve; all organized in time of peace into brigades, divisions and Army corps, with the necessary auxiliary and special troops.

By joining the Reserve Corps one becomes a part of an organization that is being developed to save time and money and to reduce the expense of maintaining a war-time organization. During the war many "misfits" were placed in charge of departments because no preparation had been made for motor transportation. The present plan is to eliminate confusion and to assign in each locality an organization recruited so far as possible from ex-service men and whenever it can be done to retain their World War designation. These men will be formed into a skeletonized organization, with a commanding officer and the necessary aides. As the organizations fill up, motor repairmen of various degrees of skill will be assigned. There will be no demands on one's time other than to sign the necessary papers for joining, undergo a physical examination, and if one is anxious to progress in the Service to take up the Army Correspondence Course that endeavors to teach potential soldiers the rudiments of the Service.

Local pride will be involved in the formation of any given organization. It will retain its identity in skeletonized form throughout the period of service. A certain motor-repair battalion is now attached to the First Army, with its commanding officer and his adjutants, the Headquarters Organization, Companies A, B, C and D with their captains and lieutenants; even the medical and dental officers have been assigned to this organization. In case of war the officers, who have become acquainted with their commander, their associate officers and their assistants will be ordered to mobilize. There will be little confusion in terminating one's affairs and gathering at the various contact points.

The terrific change that emergencies of this kind entail upon everybody is well known and there is no question about the advisability of preparing now for the war that may or may not come, and as we have been more or less active in criticising the lack of forethought on the part of those responsible for our preparedness or lack of it, it is our duty to stand back of this movement and interest ourselves and our neighbors in joining this organization that costs the individual little or nothing and entails no additional expense upon the Government. We must organize, preferably with the men who have seen some service. However, any man of fair education and some executive ability should be able to pass the examination and obtain a commission in this reserve force, and as time goes on fit himself for promotion. No doubt hundreds of men would be glad to take part in this reserve movement, if they understood the situation. As citizens and as engineers it is our duty to spread the idea as far as possible.

Full details of the Reserve Corps may be obtained from the various Corps Area Headquarters listed below:

First Corps Area, Boston.
Second Corps Area, Governors Island, New York Harbor.
Third Corps Area, Baltimore.
Fourth Corps Area, Fort McPherson, Ga.
Fifth Corps Area, Fort Hayes, Ohio.
Sixth Corps Area, Chicago.
Seventh Corps Area, Omaha, Neb.
Eighth Corps Area, Fort Sam Houston, Texas.
Ninth Corps Area, Presidio, San Francisco.

While the automotive industry is particularly interested in this movement, the chemist can join the Chemical Warfare Branch; and the metallurgist, the Ordnance, as well as the Quartermaster Corps. In fact men of any trade or profession may enter this reserve, knowing that their particular qualifications will be appreciated. Prospective officers may be accepted without examination prior to Nov. 1, 1923, upon stating their previous experience. Other applicants will forward with their applications a record of their civil experiences, as the intention of the War Department is to have each man in the position best suited to his particular ability or talent.

Aircraft-Engine Practice as Applied to Air-Cooled Passenger-Car Engines

By S. D. Heron[1]

Annual Meeting Paper *Illustrated with* Photograph

THE discussion of Mr. Heron's paper, presented at the 1922 Annual meeting, includes written contributions and the remarks made at the meeting. For the convenience of the members, an abstract of the paper is printed herewith, together with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed, and to the illustrations that appeared in connection therewith, can do so readily.

ABSTRACT

STATING that most of the copying of aircraft practice in post-war car-design has proved a failure because the fundamental difference in duty has not been realized, the author proposes to show wherein the automobile designer and the engine builder can profit by the use of practice developed for air-cooled aircraft engines and, after generalizing on the main requirements involved, discourses on the simplicity of layout of the efficient air-cooled cylinder as a preface to a somewhat detailed discussion regarding cylinder design and performance, inclusive of valve location, type of finning and form of cylinder-head.

Cylinder material, cooling surface, port arrangement for in-line engines, and the camshaft and valve-gear arrangement most desirable are subjects treated at length and illustrated, the thought then passing to a consideration of sleeve-valve types, temperature and pressure air-cooling, in such detail as to include many engineering data; and similar treatment is accorded the subjects of air supply, a cooling system for in-line engines, air-flow direction and the necessary quantity of air. Desirable types of fan, spark-plug, piston and fuel are considered upon somewhat broadly. The author contends (a) that scaling-down of design in internal-combustion-engine cylinders is a safe process, while scaling-up is decidedly unsound; (b) that, since thermal troubles have been the greatest cause of difficulty with air-cooled cars, a consideration of the design capable of continuous full-throttle operation is likely to demonstrate the ease with which the relatively mild thermal difficulties of an air-cooled car can be overcome.

Appendix 1, by C. Fayette Taylor, treats the subject of the experimental development of air-cooled engine-cylinders specifically, reviewing briefly the methods used by the Engineering Division in developing and testing cooling units for both air and water-cooled engines, and discussing some of the results obtained with several of the air-cooled cylinders mentioned in the paper proper. Performance investigations of experimental cylinders are described and commented upon, features of construction and tabular data that are given being largely pertinent. Laboratory experiment in regard to exhaust-valve cooling is related, together with mention of the experimental results with internally cooled valves. Subsequently, many air and water-cooled-type comparisons are made, the conclusion being that there will be a rapid and healthy growth of the air-cooled type of powerplant for automotive vehicles.

Appendix 2, by E. H. Dix, Jr., has as its subject the foundry production of air-cooled cylinders with the fins cast integrally and first describes the experience of the Engineering Division foundry in casting aluminum-alloy cylinder-heads, numerous illustrations of castings being included. The suitable gating for aluminum-alloy casting is discussed, supplementary illustrations being presented, and the conclusion is reached that the experience related tends to show that air-cooled cylinder-head castings of the types illustrated are far from being bad production propositions.—[Printed in the January, 1923, issue of THE JOURNAL.]

THE DISCUSSION

L. H. POMEROY:—My experience with automotive engines generally is that no small amount of the difficulty in maintaining silence of working and general freedom from erratic behavior is related to temperature variation. It seems to me that any development that increases the temperature range in an engine is to be regarded with suspicion. There is, of course, ample evidence that air-cooled engines are reliable mechanically, but the buying public demands silence as a first condition. Furthermore, this question of temperature and its effect upon bearing clearance is intimately connected with what may be termed local vibrations such as those arising from loose wristpins, camshaft bearings, and the like. Even starting from cold seems to have its difficulties, although my experience of this is confined to one or two examples. Nevertheless, it is reasonable that the volume of water in a water-cooled system acts as a thermal-storage arrangement, preventing the engine from rapidly getting chilled to the bone so that the oil-films in every bearing become glutinous.

Mr. Heron apologizes for the high internal friction of the universal test-engine. Is there any difference between the air and the water-cooled cylinders in this respect? If the effect of air-cooling is to cause a greater vitiation of the qualities of the lubricant on the cylinder wall than is now the case, the effect on the mechanical efficiency at part throttle is a serious matter, particularly as it takes as much horsepower to drive the engine as it does to drive the car at speeds of the order of 20 m.p.h.

C. P. GRIMES:—Mr. Heron has gone into many things that the automobile builder might not meet because he has not found it necessary to develop such high brake mean-effective pressures as Mr. Heron mentions. We feel that, whereas the circumferential fin might lower the temperature in its immediate vicinity, there is a considerable gain in having the fin parallel with the axis of the cylinder, much as we have shown it, as it assists greatly in carrying the heat from the head through the fin down to the lower parts of the cylinder, to be radiated better there, perhaps, than could be done if there were

a single fin around the circumference at the head, or combustion-chamber, only, because the other fins could not communicate with that particular fin in taking away and dissipating the heat.

In following water-cooled practice very closely for 12 years, I have observed this: Supposing that the air-temperature were about 94 deg. fahr. and that the automobile were traveling on a level road with a water-cooled radiator, it would be found that the air passing through the water-cooled radiator would rise in temperature from 26 to 29 deg. fahr. while averaging from 25 to 50 m.p.h.; whereas, in our car, under the same conditions of load, pavement and air-temperature, the air would rise in temperature a little more than 80 deg. fahr. In other words, every cubic foot of air worked on in the air-cooled system would suffer a rise in temperature a little more than twice that in the water-cooled system.

I was pleased to hear that the Engineering Division has developed a fan that has an efficiency of 74 or 75 per cent. That is the first fan of that type with so high an efficiency that I have heard about. In my experience, the efficiency of a fan behind a radiator is decreased because the radiator and the engine are so close to the fan that the latter cannot work as it should. The result is that the air-efficiency of the fan is very low; whereas, in air-cooled practice, we place the fan in a scroll housing and have been able to get from 65 to 68 per cent actual efficiency in moving the air. The air-cooled engine has, of course, no water-pump. In our construction the fan is directly on the crankshaft and has no extra bearing-losses. The fan has an efficiency from two to three times that of the average fan behind the radiator.

Regardless of the cooling medium used, the average engine must dissipate a certain average amount of heat by way of its radiating system for any given average speed of operation. The direct air-cooling method allows us to raise the temperature of each cubic foot of air handled more than twice the amount possible when using a water-filled radiator-core and, at the same time, maintain a cooler cylinder-head. It also allows us to build our fan into a scroll and operate it at an efficiency of from two to three times that possible when using a blade fan close-up behind a cellular radiator. It avoids the power loss incident to a water-pump and, in our case, avoids the use of a belt drive with its inherent power loss, to say nothing of the expense and care of the additional fan bearing usually required. By careful measurement, our cooling fan was found to absorb less than 0.3 hp. at a car speed of 20 m.p.h.

The question of starting has been brought up by Mr. Pomeroy, who spoke about the engine's cooling-off rapidly as soon as it was stopped. I cannot see but what that speaks very favorably for the efficiency of the cooling system. Briefly, in our latest car we have an electric heater-coil in the carbureter in conjunction with a distinct and separate carbureter auxiliary to the main instrument. If a button on the dashboard is pushed, this will raise a valve from the auxiliary carbureter to the main yoke passage. It will allow 80 amp. of current to flow through a heating-coil, one end of which is submerged in gasoline, the whole coil being insulated from the carbureter by a porcelain tube. At 20 deg. below zero, fahr., at which temperature I remember having seen these tests conducted, it was necessary to push the button for 40 sec. This allowed 80 amp. of current to flow through the heating-coil, which developed a red heat, and transformed the liquid fuel that, in this case, was very nearly kerosene, the ordinary fuel purchased at a filling station, into what looked to me to be a kind of gray fixed-gas. It did not seem to condense on metal of any kind and seemed to flow up through the suction yoke. Forty seconds was sufficient time to heat up the chamber and to produce a sufficient volume of gas to fill entirely the suction yoke of the engine. The next operation in starting was to push the starting-switch, as always is done, and draw 400 amp. of current, as is the case with any engine of similar size. After the engine had been turned-over for not to exceed 5 sec., to get a charge into the cylinder, it started. If desired, the engine would continue to run on this small auxiliary carbureter, at a road speed of 18 m.p.h., and with a five-passenger load, for a week.

I wish especially to call attention to the fact that, whereas we were using 80 amp. of current for 40 sec., this is far less than the 400 to 450 amp. that would be required to crank the engine; in other words, we used not to exceed one-third the energy from the storage-battery that is customary on many other cars. After this primer has produced the fixed gas and has allowed the spark-plugs to work upon a combustible mixture and to start, the entire exhaust of the engine is passed through a cast aluminum vaporizing heater that is located directly above the carbureter. This heater, when a room-temperature of 84 deg. fahr. prevails, transforms the gasoline and the air into a dry condition, with a temperature of 160 deg. fahr. $\pm$ 5 deg. fahr., throughout the entire range of the engine, with the throttle either wide-open or in ordinary running position, excepting that at 15 m.p.h. and less it is slightly cool. If a draft of air on the crankcase is provided, to maintain the oil at a reasonable temperature, this powerplant can be used at 100 to 110 deg. fahr. in the shade, if desired, for sawing wood or pumping water all day, without need of worry about the cooling or the heat effects on the engine.

H. S. McDEWELL:—Although I have a more or less open mind on the subject of air and water-cooled engines, it is impressed upon me that, if the same quality of research brain-power and quantity of research endeavor had been put into the problem of water-cooling as have been put into the problem of air-cooling, the resulting water-cooled engine would differ as much from its present type as does the present-day high-duty air-cooled engine from the original attempts with this latter method of cooling. It is my impression, an impression that I think is thoroughly justified, that such work as has been done in investigating the cooling of the water-cooled engine has been of a decidedly haphazard nature. I feel, therefore, that there is a vast field for improvement in water-cooling, and that some of the handicaps and limitations that have been placed on it by the work of Mr. Heron and his associates, both in this Country and in England, should be overcome.

With regard to the so-called grafting of aircraft practice on post-war cars, it would seem, particularly with the cars in which such practice is advertised, that the engineers and the designers responsible have failed to keep in sufficiently close touch with actual aircraft design and development to be able to approach good aircraft practice even relatively, and it is to this fact that failure has been due. In some cases actual aircraft practice has been used, but not advertised. In these cases, the results have been entirely satisfactory. Successful aircraft practice is nothing but good design and, therefore, if incorporated into any machine, it must be successful provided the service conditions are not such as to prohibit its use. The fact that tests of the single-cylinder engine apparently cannot be approached exactly in the multi-cylinder engine does not, in my opinion,

to air-cooled engines, the trouble might possibly be caused by the fact that the heat transmitted from the piston skirt and rings to the cylinder wall by way of the sleeve or sleeves would be much less than in the case of direct transmission, such as occurs in a normal type of engine.

I cannot help feeling that Mr. Heron has neglected oil-cooling in his paper. He has talked entirely about air-cooled cylinders and has altogether neglected to state that the average air-cooled engine, and water-cooled engine too, for that matter is to a large extent oil-cooled. He does not state whether, when he used the internally cooled valve, he depended on oil for the external abstraction of the heat from the valve. It has been my experience that when an attempt is made to direct the flow of air, as is necessary with circumferential fins, particularly when the air is stirred-up by a propeller-type fan, the baffling required is not as simple as it appears at first sight; in fact, it is a difficult matter requiring considerable time and experiment.

At the present state of the art, I hardly think that an exhaust turbine-driven fan is a commercial possibility. My impression has been that, at McCook Field, it has been a case of about 1 hr. of flight and 24 hr. of overhauling of the turbine-driven unit, although such conditions may have been improved since I was familiar with them.

I wish to commend Mr. Heron on his statement of views with regard to the inadvisability of scaling-up designs and the entire safety of scaling them down. Starting with large dimensions is much more apt to cause trouble than starting with small dimensions. If, with a large-dimension design, it is possible to overcome all troubles, the inference is that when an attempt is made to build smaller engines of the same relative design, the troubles overcome in the large design will not be encountered.

THOMAS MIDGLEY, JR.:—There is not much that I can add to what most of you have already seen. The copper-cooling development is a perfectly obvious thing. The substitution of copper for cast-iron is due to the fact that copper is the better conductor of heat; with the same disposition of material an engine is cooled better by using copper than by using a ferrous metal. The development of the copper-cooled car was not so much the development of a cooling system as it was the development of a car. We felt that we had a good engine and we wanted a good car to put it in.

MR. GRIMES:—What is the method of putting the copper on cast-iron cylinders? What are the temperatures of the air coming from the fins, and the operating temperatures of the head, or of the walls of the cylinder, under either level-road or full-power conditions?

MR. MIDGLEY:—We take a well-finished cast-iron cylinder and then braze on the copper fins. A research problem was involved in handling the brazing operation, as well as some technical details that had to be mastered. I do not know the actual temperature of the air leaving the fins, but it is about 100 deg. cent. (212 deg. fahr.) above normal room-temperature. The temperature in our engine with a wide-open throttle does not compare unfavorably with the temperature that exists in a water-cooled cylinder under the same conditions.

MR. POMEROY:—Does that depend on the fact that the cylinders were small in dimensions? Would the same reasoning hold for a larger cylinder?

MR. MIDGLEY:—Yes. We have run break-down tests on our engines. We get the same brake mean-effective pressure and the engine is just as good. After several thousand miles of operation, a water-cooled engine, as

compared with a copper-cooled or air-cooled engine, has lime, calcium salts and all sorts of impurities in it, for the water found around the United States is not water, but a salt solution. About 1-16 in. is left on the outside of the cylinder, inside the water-jacket, and what good does it do to put the water around it after that? Many cars are sold for the third and fourth time, not because the bearings have become loose, but because there is about 1-16 in. of lime outside of the cyinder, and then the engine runs roughly as a result. If you could get the lime out, you would again have a fair operating mechanism. The copper-cooled engine runs at approximately the same temperatures as a water-cooled engine under the same conditions. The hot gas inside the cylinder does not know in what way it is being cooled on the outside; it merely knows how well it is being cooled.

C. L. LAWRANCE:—There is expansion in the cylinders of air-cooled engines, causing greater valve clearances when hot, but there is also expansion in the cylinders of water-cooled engines that have the standard overhead-valve and push-rod and increased clearance. Nevertheless, many first-class cars are built with this method of valve operation. If there is trouble from the enlarged clearance due to such expansion, it is possible to regulate the clearance so that it will stay practically the same at all cylinder temperatures. With properly designed pistons, I cannot see that there should be any more noise from a properly designed air-cooled engine than from a water-cooled engine.

It has been said that there is an unusually high frictional resistance in a single-cylinder air-cooled engine. This is equally true of water-cooled, single-cylinder testing engines. I believe that they do not differ in any respect; in fact, there is very little frictional resistance in some air-cooled engines. I know of one engine tested at McCook Field that showed a mechanical efficiency of 92 per cent.

Mr. Grimes has said that the high mean-effective pressures mentioned by Mr. Heron are not required. That is true. As high mean-effective pressures are not required, the extreme cooling required in aircraft practice also is not necessary, but it seems to me that it is desirable to remove the heat from the place nearest to the point at which it is produced, the combustion-chamber. Why is it not logical to cool the top and sides of the combustion-chamber, and not merely the sides and barrel of the cylinder? If that were done, it would be possible, probably, to have less cooling medium and a slower flow of air and, perhaps, to use less power in the blower.

In water-cooled engines, it is usual to cool the cylinder-head. It seems to me that the greatest tribute to air-cooling is the fact that engines can run satisfactorily with practically no cylinder-head cooling. With proper study of the conditions of the head, air-cooled engines for motor cars can be made to cool in the same sizes as engines with practically no cooling except the very smallest flow of air over the head.

C. B. DICKSEE:—There are many advantages to be claimed for longitudinal fins, chiefly because all the cooling air passes directly where it is most needed, over the cylinder-head, particularly if the direction of airflow is that adopted by two builders of air-cooled cars, in which the cold air strikes directly on the hottest part of the engine.

There is no reason why there should be any doubt about the kind of junction between the steel fin and the iron barrel with cast-in steel fins. Our firm builds small engines that use this type of cylinder. When cylinders have been cut-up, we have found that the weld between the fin and the iron barrel is perfect. These cylinders require care and attention in the foundry, but are produced readily at a low cost. When a nail or some light steel instrument is run round on the fins, they will ring like a bell if tight; if they are not tight, they will jangle. Whenever we have cut-up a cylinder that has rung true, it has invariably been found to have a perfect weld.

The microphotograph, Fig. 38, shows that the weld we obtain is perfect. The white part, which is the fin, tapers off to a point. That is because the steel has actually been washed away by the iron in producing the weld; about 50 per cent of the steel that was inserted into the iron has actually been fused away. Fins are not all fused

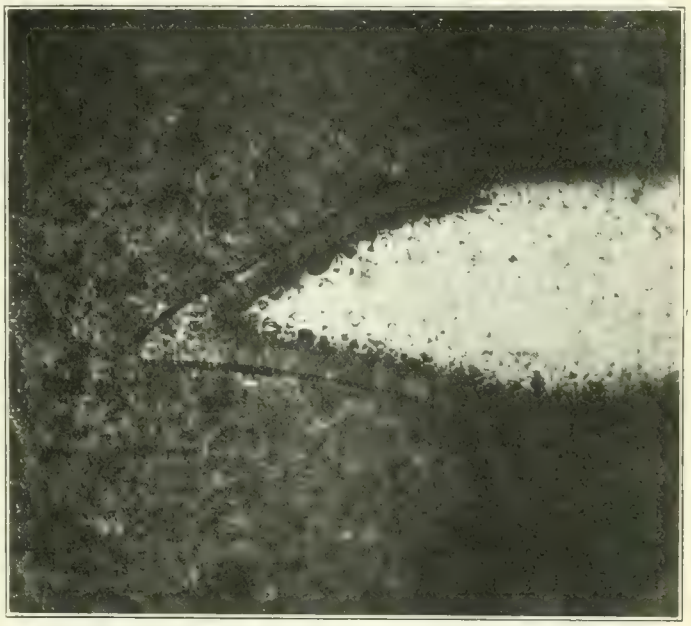


FIG. 38—MICROPHOTHGRAPH OF THE JOINT BETWEEN AN IRON AIRCRAFT-ENGINE CYLINDER AND THE STEEL RADIATING FIN THAT WAS WELDED IN PLACE

away to the same extent, but there is invariably a certain amount of washing away and perfect adhesion in almost every case. We get scarcely any cylinders now that fail to ring true.

With reference to cleaning the cylinders, where the ends of the fins are turned over there is possibly some difficulty in cleaning the ducts of longitudinal fins, but compressed air will clean them as readily as it will clean circumferential fins, whereas a piece of stovepipe put on over the fins is easily slipped off and the duct cleaned out with a brush. I have found that a considerable amount of filth has very little effect on the cooling. The air in the neighborhood in which our plant is located is particularly dirty and engines that have been run for protracted periods, some of them more than 2000 hr. on full load, have been found to have the cooler parts of the cylinder completely covered with fluff and filth, but the engines worked perfectly under those conditions. Where the temperature is high enough to dry off oil, the dirt will not stick.

Referring to Mr. Heron's statements as to the pressure loss with longitudinal fins, we have measured the loss of air pressure through the ducts and have found the chief loss to be an entry loss; that is, most of the air pressure is used in accelerating the air from the slow stream approaching the cylinder to the rapid stream

fahr. in the shade, the cylinder-head is the hottest point, except the exhaust-valve itself, and reaches a temperature of about 190 deg. fahr. By choking-off the air-cooling, I have raised the temperature to 450 deg. fahr. I have operated the engine at 650 deg. fahr. A temperature of 660 deg. fahr. melted a hole in the piston. When operating normally at 110 deg. fahr. in the shade, the cylinder-head temperature does not exceed 400 or 425 deg. fahr.

We made a series of economy runs at 20 m.p.h., with a cylinder-head temperature of 190 deg. fahr. When we raised that temperature to 425 deg. fahr., the average of five runs showed that there was a difference in the economy, or miles per hour, of not to exceed 1 per cent. That was not brought about solely by the cylinder-temperature. If we did not have the exhaust-heated vaporizer that really converts the carbureted gases into a dry and more or less perfect vapor, the cylinder-head temperature would control the economy; but, since we feed to the cylinders a gas that is dry, or practically so, at a temperature around 150 deg. fahr., the cylinder-head temperature is no longer a factor in economy.

S. D. HERON:—High brake mean-effective pressure, high output and large cylinders were stressed in the paper to show the relative ease with which an air-cooled car-engine can be cooled. If it is possible to produce cylinders with an output of 40 to 50 hp. per cylinder that will run on full throttle for 8 hr. per day without cooling or other trouble, there should be no difficulty in producing an efficiently cooled automobile engine. In this connection, it is well to consider that a 240-cu. in. capacity automobile-engine will run most of its time with an output of less than 10 hp., whereas an aircraft engine of similar capacity must be capable of delivering about 70 hp. at a speed of about 1800 r.p.m. continuously.

Cooling is really the least of the difficulties with an air-cooled car-engine; this point should really give no trouble at all. Silence is likely to be the most troublesome feature. The problem of silence has been very satisfactorily solved in at least one air-cooled car now on the market, but it is likely that attempts to produce air-cooled car-engines capable of continuous high speed, say 60 m.p.h. and more with engine capacities of 200 cu. in. or less, may necessitate the development of much new-design technique to secure such performance with real engine-silence. If an air-cooled car-engine with the quality of extreme silence of operation is required, the sleeve-valve type is well worthy of consideration, and I think that there is little doubt that this type of engine can be air-cooled successfully.

When Mr. Pomeroy speaks of raising the temperature of the mass of material around the bearings by 200 deg. fahr., I can only assume that he is exercising his sense of humor. That he should believe that the bearing temperatures in air-cooled engines of decent design are 200 deg. fahr. higher than in water-cooled engines does not seem possible, any more than it would seem possible for bearings working under such a handicap to function for anything but a very limited period. Mr. Pomeroy jibes at the starting qualities of air-cooled engines, while knowing full well, of course, that the cooling system has little or nothing to do with the starting of an engine. The starting of air-cooled engines at McCook Field is at least as certain as that of the water-cooled types. In most cases, air-cooled aircraft-engines are started by priming, swinging the propeller for a few revolutions and using the booster magneto with the crankshaft at rest. Even with an air temperature of 10 deg. fahr., a start is generally obtained at the third or fourth attempt. It would

MR. MIDGLEY:—Heat flows from the head to the fins at the side of the cylinder.

MR. NEVINS:—What insulating material is used between the manifold and the head of the cylinder? Is it copper and asbestos?

MR. MIDGLEY:—Yes.

A. M. WEBB:—Is it possible to maintain the alignment of the valve-stem, which is in a separate casting, with the valve-seat that is in the cylinder-head, especially after the engine has been taken down several times? Inasmuch as the gasket is inserted between these two points, any variation in the thickness seemingly would spoil the alignment.

MR. MIDGLEY:—This gives no trouble. There should be no occasion to remove the superstructure from the cylinder. After having driven several cars thousands of miles we have had no trouble.

DR. H. C. DICKINSON:—A subject that has been exercising persons interested in fuel is the uniformity of the cylinder temperature. In fact, some of our members have become interested in steam-cooling systems for the sole purpose of maintaining a uniformly high temperature in the cylinder-walls. Has anyone anything to say on the subject of the maintenance of a uniform cylinder-temperature, that is, uniformity at variable time, with air-cooled cylinders?

MR. [illegible]:—I would say, as I felt that the high temperature of the air-cooled engine was a big factor in the economy of operation of the fuel, recently research work has convinced us that the temperature of the cylinder is not limited to the economy of the engine in any way. Of course we know that if the jacket is cracked so it passes water it will not work as well as if it were watertight.

At 20 m.p.h. under temperature conditions of 90 deg.

be of interest to know how many water-cooled car-engines would respond to such starting methods with an air temperature of 10 deg. fahr.

While apologies are due for the high internal friction of the universal test-engine used at McCook Field, and this is true of most single-cylinder test-engines, it may be well to notice that the apology is equally due whether the cylinder under test is air or water-cooled. Reference to Table 2 in the paper clearly illustrates this point. The friction mean-effective pressure of radial air-cooled engines has in general proved to be less than 15 lb. per sq. in., which is at least as low as that of most water-cooled car engines. That we are dealing with very high internal temperatures in air-cooled engines is very much open to doubt. The tests detailed in Table 4 of the paper show that a Liberty cylinder with 0.025 in. of scale on the walls runs about as hot as an air-cooled cylinder of equal output. It is not unusual to find 3-16 in. of scale in a water-cooled engine of aircraft type, to say nothing of what is likely in badly cooled water-cooled car-engines; thus the wall temperatures attained under such conditions are likely to be at least as high as in air-cooled engines.

CHAIRMAN T. J. LITLE, JR.:—What about the radiator?

MR. HERON:—On the Mexican border considerable trouble is experienced with scale in aircraft radiators. I have heard of cases where replacement was necessary after only 3 weeks of service.

My remarks on axial-fin cylinders were made to point out that there are other methods of designing air-cooled engines. Mr. Grimes and other speakers have referred to the advantages of the axial-fin type of cylinder, claiming among them that (*a*) the heat is conducted across the head to the fins on the barrel, and there is dissipated; (*b*) the axial fin conducts the heat down the barrel to the lower end, tending to equalize the temperature distribution; and (*c*) the cold cooling air is directed on the point where it is most needed.

Regarding claim (*a*), this is admitting that no attempt is made to dissipate the heat at the point where it is received by the wall. There is no question that the most efficient cooling is obtained in any engine, whether air or water-cooled, if the heat given to the walls is dissipated almost entirely at the point of reception. The circumferentially finned aircraft-engine type of air-cooled cylinder with the crown of the head, the valve-seats and the ports thoroughly finned, and with free access of air to all the fin cells, approaches the condition of heat dissipation at the point of reception much more closely than any axial-fin type yet seen. With an aircraft type of cylinder, removal of the fins from the barrel has very little effect on performance, but the result is very different if the barrel finning is left and the head finning removed, disastrous overheating being the immediate result.

CHAIRMAN LITLE:—That is because the engine is running wide-open. That would not necessarily apply to a passenger car.

MR. HERON:—No. On the other hand, by using highly efficient cooling methods, much less air is required; this results in an engine that warms-up quickly and has a low friction loss. When the power required to propel a car at 25 m.p.h. is considered, the percentage of the indicated power normally wasted in engine friction alone is appalling.

Regarding claim (*b*), the axial conduction of heat down the cylinder barrel in circumferential-fin-type cylinders is achieved readily by the use of a thick-section barrel. This would seem to be a more certain method of securing axial heat-flow than by conducting the heat from the barrel across the doubtful thermal joint of a cast-in piece, to the fin, and thence down the fin to the base of the barrel. Claim (*c*) is really rather amusing in view of the fact that most users of axial finning practically ignore the need for head cooling by either omitting head finning entirely or using such a fin layout that the cooling air practically is prevented from penetrating to the hot surfaces most requiring it.

A parallel to the cooling conditions of the average flat-head axial-fin cylinder would be produced by a water-cooled engine without water around the valve-seats, the guides and the ports. Much of the valve trouble in water-cooled car-engines today is due to a partial existence of this state. The designers who have spoken of the advantages of axial-fin cylinders have based their claims on experience of small-capacity low-duty cylinders. In this connection, it is worthy of note that no successful large high-duty axial-fin cylinder has yet been produced. That the axial-fin cylinder works in the sizes in which it has been produced is no proof of its soundness. If the advocates of this form of construction would submit their faith to the test by attempting to produce a 6-in.-bore axial-fin cylinder, they probably would obtain a very thorough knowledge of the advantages of scaling-up in showing-up the fundamental soundness or unsoundness of types of design in internal-combustion-engine cylinders.

CHAIRMAN LITLE:—What about the relative advantages of the integral and the brazed-on fin?

MR. HERON:—The integral fin is decidedly a better production proposition than the attached fin, whether brazed-on or cast-in.

CHAIRMAN LITLE:—How about performance?

MR. HERON:—The limit in output with integral fins has yet to be reached. To date, it has been found possible with integral fins to secure all the cooling needed on any cylinder size tried yet.

That the cooling air in the car he represents has twice the temperature rise that occurs in a water-cooled car is claimed as an advantage by Mr. Grimes. Mr. Grimes states also that the heat-loss to the cooling-air is equal in air and in water-cooled engines. I do not know what the average heat dissipation per brake horsepower is in a water-cooled car-engine. Prof. E. H. Lockwood spoke of 50 to 70 B.t.u. per b.hp.

That an engine causes a large temperature-rise in the cooling-air is by no means an advantage, necessarily. It may mean merely that a large amount of heat is rejected to the cooling-air when it might more usefully be given out through the crankshaft. From Mr. Grimes' figures in his recent paper on Air-Cooling of Automotive Engines[2], it appears that the minimum heat-loss from the cylinder walls to the cooling-air in the engine he describes is 88 B.t.u. per b.hp., which is at least three times as great as it is in an air or water-cooled aircraft engine.

While standard service-type aircraft-engines will at times run 300 hr. in flight without overhauling of the exhaust-valves being necessary, it may be well to point out that such a test is much less severe than a 100-hr. full-throttle test on a single-cylinder engine. I agree with Mr. McDewell that excellent cooling can be obtained with tulip valves having thick rims; the thick rim is, however, as explained in the paper, a safeguard against local overheating if the valve should start to blow and, in any case, it has a tendency to reduce the temperature

[2] To be published in an early issue of THE JOURNAL.

differences around the circumference of the valve. Fracture of the rim of a tulip valve is a rare occurrence in my experience. In fact, I have heard of only one case, in addition to that quoted by Mr. McDewell, the fracture being due to faulty heat-treatment, cracks and resulting in severe impact loads. I am glad to note the commendation of the tulip valve as against the flat-head or mushroom type. I understand that the Wright Aeronautical Corporation has reached conclusions similar to those of Mr. McDewell and the Navy as a result of very extensive comparative testing.

To the best of my knowledge, the use of the tulip valve in modern aircraft engines has grown mainly out of the work of the Royal Aircraft Establishment, although I machined a set of tulip valves for an early aircraft engine 17 years ago when I was an apprentice. The reasons that led the Royal Aircraft Establishment to adopt tulip valves may sound amusing at this date; while testing with very hot-running air-cooled engines, it was found that flat-head exhaust-valves always assumed tulip form after a period of running. This led to the obvious conclusion that the tulip shape might well be adopted for the initial form of the valve. Neither greater gas-passing capacity or more efficient cooling relative to the mushroom type, now generally considered to be attributes of the tulip type, had any bearing on its adoption.

I think that an engine of the B. S. A. type, that is, without a fan, would not prove satisfactory under conditions of constant low-gear operation for many miles either through deep sand or on steep mountain grades. This design has given excellent results on climbs of 2 miles of 1 in 8 grade in low gear. Under these conditions, an excessive temperature-rise of the cylinder is prevented by heat storage and radiation; and the first factor, of course, is subject to a time limit. The cooling of this car and other British types lacking a fan is really surprising and demonstrates the capability of an air-cooled car-engine. The road conditions in this Country are, of course, very much more severe than in the United Kingdom, where the lengthy mountain grades and long stretches of deep mud and sand found in this Country are unknown. Nevertheless, my experience with the B.S.A. car would lead to the conclusion that the relatively large engine capacities required by the domestic market would, to a very large extent, balance the superior road conditions that these small-capacity two-cylinder fanless British designs enjoy, and that an air-cooled engine that will literally go anywhere in this Country will need but a relatively small amount of fan-supplied air.

The fuel used for the tests described under "Form of Cylinder-Head" on pp. 33 and 49 of my paper was 80 per cent of aviation gasoline with 20 per cent of benzol and was used generally for all the test results quoted in the paper. The compression-ratio in the flat-head cylinder, Type-I, was 5.85 to 1 and in the hemispherical-head cylinder, Type-J, it was 5.27 to 1.

With reference to the Type-K cylinder, satisfactory compression tests with aluminum and cast-iron heads were not obtained. Owing to defects in the method of valve-seat attachment, fracture of the exhaust port occurred in both aluminum heads that were tested, although no trouble has developed in well over 100 hr. of running with the cast-iron head. The cast-iron Type-K cylinder, however, proved superior in all respects except that of weight to an aluminum cylinder of somewhat different design but with the same bore and stroke. I am rather at a loss to explain the high output and satisfactory operation of the cast-iron cylinder when the very high wall-temperatures are considered. Probably the smooth outline of the hemispherical combustion-chamber, with the resultant smooth gas-flow over the hot surfaces is, in conjunction with the lack of large red-hot areas, mainly responsible for the results obtained, when the cooled valve is used.

Oil-cooling in air-cooled engines was not dealt with in the paper, as this was stressed in my paper on Some Aspects of Air-Cooled Cylinder Design and Development[4]. The efficiency of the internally cooled valve is not dependent on oil for the external abstraction of heat from the stem, although the oil assists this as it does with a normal valve. The type of internally cooled valve developed by the Engineering Division was evolved on an air-cooled cylinder with an open valve-gear and unlubricated valve-stems and guides.

Uniform distribution of air-flow to V-type circumferential-fin air-cooled engines has not proved to be difficult to secure, although of course experiment is necessary. The R.A.E. and Renault V-type engines, having scoop cowls with a propeller directly in front of the entrance to the cowl, needed but little in the way of directional baffling. The most suitable form of cowling is determined readily by a mock-up of the engine, the air being driven into the cowling by a fan and the air distribution checked with a small pitot-head.

While the exhaust turbine-driven fan is probably visionary, it is nevertheless a possibility and was mentioned on that account. While the early exhaust turbine used at the Engineering Division gave considerable trouble with overheating, this is no longer true of the present designs in which the wheel apparently does not, under any conditions, reach anything near a red heat. The whole gas-turbine itself is now extremely reliable.

I should like to take this opportunity of expressing my regret at the death of Mr. McDewell and my sympathy for his family. By his death, the industry loses a very powerful influence toward progress. He was an example of that unfortunately very rare being, the extremely practical engineer who has a thorough knowledge of pure science.

While there is possibly no reason why there should be any doubt about the junction between a cast-iron barrel and cast-in steel fins, nevertheless, in practice, there is considerable uncertainty. Ringing the fins to detect unsoundness is an elaborate proceeding. To admit that it is necessary is just another way of stating that the bond is uncertain. Mr. Dicksee's methods of testing merely add to my opinion that cast-in pieces or inserts of any description are a nuisance in any foundry. Any foundryman is well aware that even cast-in chaplets are likely to be poorly bonded to the casting, and that their use results in danger of leakage under pressure where they are used. I may say that Mr. Dix concurs with my opinion regarding the use of cast-in pieces, both of us having had extensive and rather unpleasant experience with cast-on cylinder-heads and cast-in valve-seat inserts. With reference to cleaning axial fins, the matter is not as simple as Mr. Dicksee states; for instance, in most overhead-valve engines, removal of the fin jacket involves the detachment of the intake and exhaust pipes and usually of part of the valve-gear. In any case, the very presence of the jacket means that the presence of dirt is not at once evident on casual inspection.

While the presence of a considerable coating of dust and

(Continued on p. 50)

The Use of Acetone in Composite Engine-Fuels

By R. F. Remler[1]

INFORMATION regarding the use of acetone in composite fuels is not extensive in technical literature. Most of it is found in recent patents, the majority of which have been issued in foreign countries. This is due to the higher price of motor fuel in those countries, which has stimulated the search for substitutes for gasoline. In these inquiries engineers have turned to the first possible solution that would permit the use of the present design of engine, that is, a composite fuel.[2] In selecting the ingredients of this type of fuel, they have aimed to utilize the various fuel components obtainable in their particular localities, with the result that the ones available have not always been miscible; or, if miscible, they have possessed properties that are not conducive to good results. To overcome these difficulties, the engineers have been obliged to find a fuel that will act as a common solvent for the various ingredients and to add other desirable properties that are sometimes lacking in the mixture. It appears from some of the recent patents on composite fuels that acetone has been chosen to fulfill this purpose.

The chemical structure of acetone differs somewhat from that or ethanol, or ethyl alcohol, being of ketonic formation. Its chemical composition, however, differs only in that it contains one more carbon atom than ethanol, their respective empirical formulas being C_3H_6O and C_2H_6O. The extra carbon atom gives acetone a higher B.t.u. value, per pound or per gallon, than ethanol, since their specific gravities are approximately the same, 0.792 and 0.789, respectively, at 20 deg. cent. (68 deg. fahr.).

Comparative Heating Values of Acetone and Ethyl Alcohol

	B.t.u. Per Lb.	B.t.u. Per Gal.
Acetone	13,476	89,477
Ethyl Alcohol	13,028	85,985

Acetone is a clear, mobile liquid having an agreeable odor and a peppermint-like taste, It is inflammable and burns with a white smokeless flame. Concentrations of acetone vapor with air up to 2.3 per cent will not flash. Above this point, there is a slight flash, increasing to and reaching a maximum violence at a concentration of 5.5 per cent of acetone vapor, and settling down to a quiet flame at 10.2 per cent.[3] Acetone has a boiling-point of 56.5 deg. cent., or approximately 133 deg. fahr., and is miscible in all proportions with the various fuels used in motor cars.

Acetone may be manufactured by a number of different processes. Prior to the war, it was made on a commercial scale only by the dry-distillation of calcium acetate. The great demand created by the war for this chemical in the manufacture of smokeless powder and as a vehicle for airplane "dope," was the direct cause of the developing of a number of new processes on a commercial basis. The production of acetone by the dry distillation of calcium acetate, however, is still the leading method of manufacture. With the acetone obtained by this process a number of higher ketones also are obtained, namely ethyl-methyl ketone, and light and heavy acetone oils that are not secured from any of the other processes, and that find an extensive use as industrial solvents.

At the close of the war there was a far greater capacity for the manufacture of acetone than was necessary to meet any possible commercial demands, and consequently a number of manufacturers ceased to produce it, while others were compelled to operate their plants at a reduced capacity. The present market for this chemical is probably about 50 per cent of that prior to the end of the war.

Acetone is an excellent engine fuel and in fact approaches the ideal in a number of its properties. Its low boiling-point and the resulting high vapor-pressure at ordinary temperatures facilitate the starting of the engine. Its homogeneity permits uniform evaporation and distribution, and, therefore, it is conducive to smooth running. Its low freezing-point, — 94.6 deg. cent. (— 138.3 deg. fahr.), prevents its solidification at the coldest winter temperatures.

Acetone will not detonate and can be used in an engine with a compression-ratio as great as 7 to 1, or with a compression-pressure up to 180 lb. per sq. in.[4] It burns with a smokeless flame, does not deposit carbon in the cylinder, and, as far as can be ascertained, has no corrosive action on the cylinder or the various parts of the car with which it comes into contact.

To compete with the other fuels, however, it would be necessary to sell acetone at one-half the price of gasoline, because of the difference in the mileage obtainable. It is not my idea even to suggest acetone as an individual fuel for motor cars, as the present price and supply would not permit such utilization.

Acetone is an excellent blending agent in reducing detonation.[5] It is miscible in all proportions with all the liquid fuels used in motor cars, and in many instances the addition of a small percentage of acetone combines two immiscible liquids into a homogeneous solution.

Ethyl alcohol, 95 per cent, as well as methanol, or methyl alcohol, are not miscible with gasoline in all proportions. As the boiling-point range of gasoline is raised, the range of miscibility of these fuels is decreased, thereby making it more difficult to add liquids of a higher vapor-pressure to the heavier hydrocarbon fuel and thus increase its volatility and distribution in the engine. These particular mixtures as well as others become miscible in all proportions on the addition of acetone in various amounts, enabling also the use of the higher petroleum hydrocarbon fuels.

The chief problems of the present-day motor fuel question regarding the use of heavy hydrocarbons are "fuel-knocks," carbon and starting. These troubles can be reduced greatly by the use of acetone in various percentages, depending upon the boiling-point range of the hydrocarbon complex used and the compression-ratio of the engine.

That acetone reduces detonation when it is used in composite fuels is probably due, first, to the fact that it reduces the deposition of carbon in the cylinders, and, secondly, to the thermolytic decomposition that takes place between 600 and 1000 deg. cent. (1112 and 1832 deg. fahr.), with the formation of methane, ethylene and carbon monoxide.[6] This reaction is endothermic and thus tends to lower the temperature in the cylinders. Acetone also will hold in solution various percentages of water, depending upon the amount of

[1] Industrial fellow, Mellon Institute of Industrial Research, University of Pittsburgh.

[2] See *Bulletin de l'Association des Chemistes de Sucrerie et de Distillerie de France et des Colonies*, vol. 39, p. 215.

[3] See *Journal of the Indian Institute of Science*, vol. 4, p. 1; see also *Transactions of the Chemical Society of London*, vol. 111, p. 267.

[4] See *The Automobile Engineer*, February, 1921, p. 51, and March, 1921, p. 92.

[5] See United States patents, Nos. 1,158,367; 1,331,054; and 1,360,872; see also British patents, Nos. 140,797, 1920, 176,329, 1922, addition to 174,360, 1922; 183,577, 1922; and 185,449, 1922.

[6] See *Berichte der Deutschen Chemischen Gesellschaft zu Berlin*, vol. 43, p. 2821; see also *Bulletin de la Société de la Chimique de Paris*, vol. 46, part 2, p. 268.

which large percentages of

engine fuels without injury

findings.

number of tests made on composite fuels containing kero-

sene, to which acetone saturated with acetylene had been added, that a smoother-running fuel was had, making it easy to start the engine and allowing a leaner mixture to be used.

Acetone is the most economical solvent for acetylene, as it dissolves approximately 25 times its volume in the gas at 15 deg. cent. (59 deg. fahr.), while ethyl alcohol dissolves only six times its volume. Numerous patents have indicated the addition of acetone for this purpose.[3]

C. F. Jurtz, in reviewing the different methods of manufacture of engine fuel by bacterial processes, finds that "acetol," a fuel consisting of alcohol and acetylene, owes its properties largely to the fact that the addition of acetone to the alcohol raises the absorption of the gas, thus increasing the volatility and calorific value of the mixture.

Summary.

From what has been said it is evident that

(1) Acetone alone is an excellent fuel, easy to start, does not freeze at the coldest winter temperature and will not detonate under a pressure of 180 lb. per sq. in.

(2) It is not only miscible in all proportions with the various fuels used in motor cars, but produces a uniform mixture when it is added in varying amounts to a number of immiscible liquids

(3) When it is added in small amounts to heavy hydrocarbon fuels, it minimizes the deposition of carbon and tends to prevent "fuel-knocks"

(4) Acetone is the most economical solvent of acetylene and, if saturated with this gas and added to composite engine fuels, will produce a smoother-running mixture, facilitate starting and permit running on a leaner mixture

SERVICE[1]

I am Service. But I am more than a name, more than a bloodless definition between dry dictionary covers.

I am energy, motion, speed.

I am common sense.

I am Alexander Bell, lengthening the tongues of men.

I am Morgan, standing between panic and prosperity.

I am Westinghouse, stopping trains with wind.

I am Pasteur, a whole life one long luminous trail of service.

Ay, I am Service!

I run through life, a golden thread with the strength of steel.

I speak all tongues.

I am the German in the laboratory, the American in the market place.

I am Smith, Jones, Brown, whoever you please that moves forward, adjusts himself to the hour, the place and the master.

I am the donkey-engine, I am the shining rails of a Harriman, I am the racing camel of the desert.

I am salesmanship incarnate.

I am the practical idealist of commerce.

I am progress.

I am the child of necessity, fathered by demand.

I pass swiftly over the swollen plains and make the epic of the wheat; I bring the sullen iron from its beds of fire.

I fill the warehouse with gold and the home with content.

I am the chemistry of action.

I was born with the world, I have made possible the ages, I am the most vital, imperious, necessary element of modern life.

I am the mother of effort, the genius of industry, the mate of life itself.

I am the ambassador of plenty.

And I am at your service.—G. B. Clarkson.

Importance of Better Automobile Head-Lamps and Proper Adjustment

By R. N. Falge[1] and W. C. Brown[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs and Diagram

THE accurate construction and easy adjustability of automobile head-lamps, though they have received much attention, are still susceptible of further improvement. If motorists realized that the road would be illuminated better, objectionable glare could be avoided and a better and safer head-lamp would be secured by properly adjusting the head-lamps now in service, an immediate and far-reaching improvement would be effected.

Views are given of tests made with the common type of head-lamp with a parabolic reflector to show the effects produced by placing the source of light at the focal point, by moving it forward, backward, above and below this point, and also by cylindrical flutes in the glass and by horizontal prisms. The head-lamp is shown to be very sensitive inasmuch as the distances from the filament to the reflector are very short when compared with those to which the light is projected. A type of lens is described that will compensate for the commercial variations in the position of the filament and at the same time distribute the light effectively, converging or diverging the rays laterally while maintaining the top or cut-off substantially at the level of the head-lamp. As the maximum intensity should be placed as near to the top as possible to illuminate the road-bed most effectively, and as the eye accommodates itself slowly to changes of intensity, the lens takes advantage of these characteristics by spreading and bending the light in each zone by different amounts.

The requirements are given for the uniform and satisfactory service of lamps and of such parts as filaments, sockets, reflectors, lenses, doors and mountings, the underlying idea being the use of devices that will obviate the necessity for focusing and leave to the motorist only the simpler adjustment of aiming.

DESPITE the progress that has been made in the last few years in improving automobile head-lamps, the conditions prevalent on the main highways of the Country, particularly those near large cities, remain unsatisfactory. The genuine concern that is apparent everywhere, the fact that State legislatures in attempting to improve conditions are finding it necessary to strengthen the laws, the fact that the Society is willing to devote an entire evening to the problem, all indicate that this matter, which has so direct a bearing on the safety of the motorist, has not been handled so effectively as have others of less importance that have to do merely with road performance and repair bills.

Without question, if motorists generally could be made to realize two facts, an immediate and far-reaching improvement in head-lamps would result. These are that

(1) It is entirely possible to get better road illumination, and at the same time prevent objectionable glare, by properly adjusting the majority of the head-lamps now in service

(2) A driver, who makes the proper adjustments now, without waiting for others to make them, not only will remove the annoyance he is causing everyone else, but also will provide himself with a head-lamp that is better and safer and that will make it easier for him to pass cars with glaring head-lamps

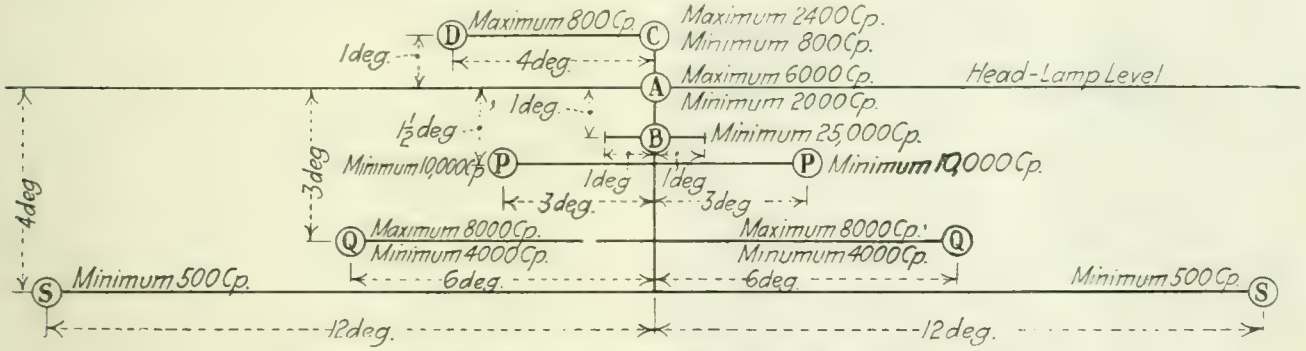


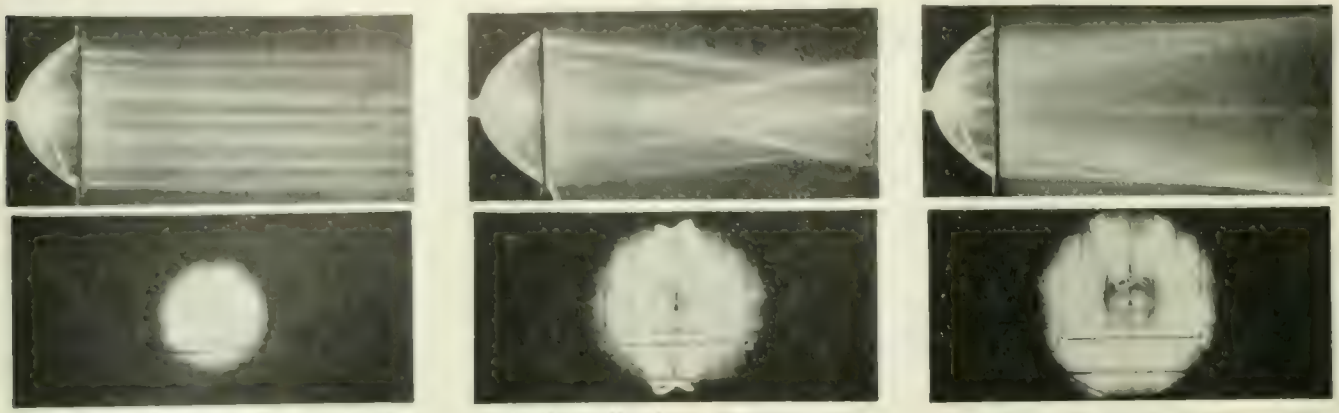
Fig. 1—S.A.E. Standard for Motor-Vehicle Head-Lamp Illumination

The erroneous idea that headlamp adjustments are made for the sole benefit of others would more easily be dispelled and the cooperation of motorists in improving conditions would be obtained more readily, if motorists were provided with accurate equipment, simply adjustable, and with instructions so clear and so comprehensive that they might easily be followed and intelligent allowance be made for such commercial variations in the equipment as would affect the distribution of light.

Underlying Principles

Good head-lamps without objectionable glare may be obtained by concentrating the rays emitted in all directions from the filament of the lamp into a shallow band of light having a candlepower hundreds of times greater than that of the lamp, directing this band of light straight ahead of the car and tilting it so that the top edge or cut-off of the beam is at the level of the head-lamp. The beam should spread to the sides far enough to illuminate the ditches and turns. A diffused light of low-intensity sufficiently strong to reveal pedestrians,

[1] Engineering department, National Lamp Works, General Electric Co., Cleveland.



Rays from Parabolic Reflector with Light Source Ahead of Focus
Cross-Section of Beam with Light Source Ahead of Focus

Rays from Parabolic Reflector with Light Source Back of Focus
Cross-Section of Beam with Light Source Back of Focus

Fig. 3—How the Relative Positions of the Light Source and the Focus of a Parabolic Reflector Affect the Distribution of the Rays and the Cross-Section of the Beam

overhanging obstructions and the like, but not enough to blind approaching drivers, is desirable above the cut-off.

Engineers, who have given the subject of automobile head-lamp illumination careful study supplemented by extensive road tests, have found that good driving-light without objectionable glare will be obtained when the rays of light, directed toward certain points on the road ahead of the car, as shown in Fig. 1, fall within certain limits that can be specified. Point *A* is directly ahead of the car and at the level of the head-lamps. Points *C* and *D* are glare points at the level of the approaching driver's eyes, 100 ft. ahead. Points *B*, *P*, *Q* and *S* are road-illumination points. When the head-lamps are 36 in. above the road, point *B* is 172 ft. ahead of the car; *P*, 114 ft. ahead of the car and 6 ft. to either side of the car axis; *Q*, 57 ft. ahead and 6 ft. to either side; and *S*, 43 ft. ahead and 9 ft. to either side. The same points are shown in Fig. 2 as they appear to the driver.

The most common type of head-lamp equipment consists of a highly polished parabolic reflector using a 21-cp. gas-filled lamp in a socket that may be moved forward or backward along the reflector-axis to compensate for variations in the position of the filament in commercial lamps, with means for spreading the beam toward both sides and in many cases for bending it downward.

The parabolic reflector may be visualized as being com-

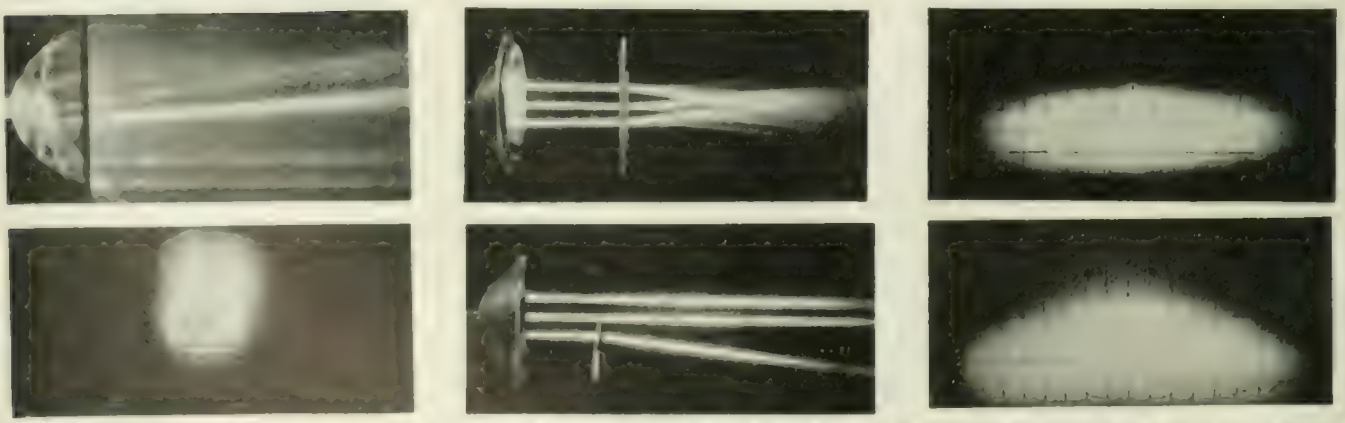


Fig. 4—The Upper Views Show the Distribution of the Rays from a Parabolic Reflector and the Cross-Section of the Beam Obtained with the Light Source in the Focus. The Lower Views Illustrate How the Light Rays Can Be Spread by Using Special Lenses. Shown at the Left is a Type of Lens Which Can Be Used with a Horizontal Prism, Both Views Being Taken from the Front. The Views at the Right Show the Cross-Section of the Beam Obtained with Diagonal Prisms. Below is a Cross-Section Beam Diagram in Which the Rays from Different Sections are Indicated by Various Arrows

posed of a multitude of small flat mirrors, each of which is so placed that a ray of light from one point, known as the focal-point, will be reflected in a direction parallel to the axis of the reflector. When all the reflected rays are parallel, the diameter of the beam at any distance would, of course, be the same as that of the reflector-opening. When the rays of light come from any other point, the angles at which they strike will be changed, and only such rays as happen to be in line with the focal-point will be reflected parallel to the reflector-axis.

The filament of an automobile lamp must have some size, and it cannot, therefore, all be located exactly at the focal-point. Rays that come from points on the filament not at the focal-point are not reflected exactly parallel to the reflector-axis. The farther from the point they happen to be, the more will they diverge. Actually, an image of the filament is reflected from every point on the reflector. These filament images increase in size with the distance and, at a point 20 or 30 ft. ahead of the car, when the filament is properly placed about the focal-point, they overlap and intermingle in a manner so as to produce a fairly uniform intensity over the cross-section of the beam. In the upper half of Fig. 3 and in the view in the upper right corner of Fig. 4, one side of an automobile head-lamp reflector has been cut away to show the light-rays passing through holes in a nearly opaque coating applied to the bulb of a 6 to 8-volt 21-cp. lamp and being redirected by the reflector. The rays were made visible and photographed in a smoky atmosphere.

The upper left portion of Fig. 3 shows what will happen to the light-rays when the lamp filament is centered accurately about the focal-point, while the lower left view shows a cross-section of the beam as thrown on a screen 20 ft. ahead. The two superimposed images of the filament were obtained by first exposing the entire beam and then placing over the reflector-opening an opaque shield with two small holes in it, one above and the other below the axis, to allow only such light-rays as come from the small areas back of the openings to escape. The images referred to are barely discernible in this illustration; they show clearly in the other two lower views. Focusing cards based on this princople are sometimes furnished to

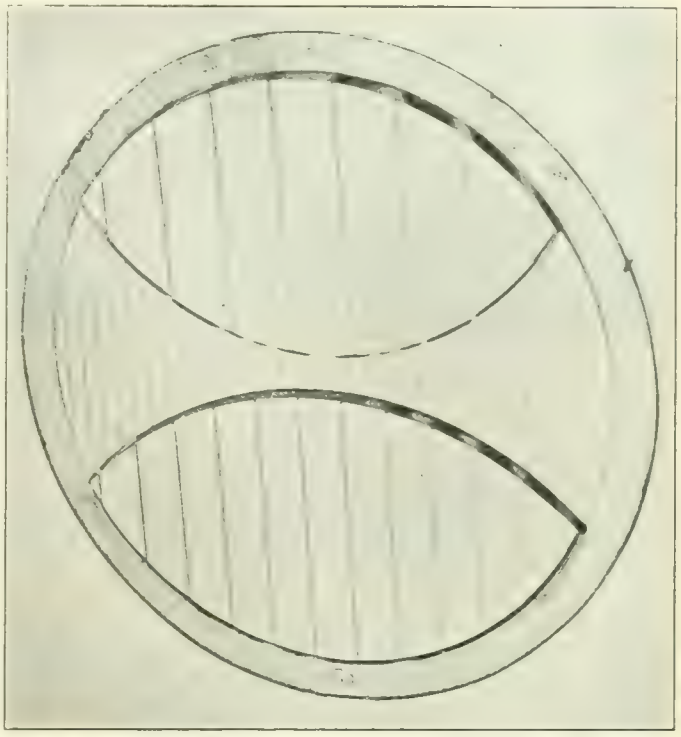


FIG. 5—A LENS DESIGN THAT SIMPLIFIES HEAD-LAMP ADJUSTMENT BY ELIMINATING THE NECESSITY FOR FOCUSING

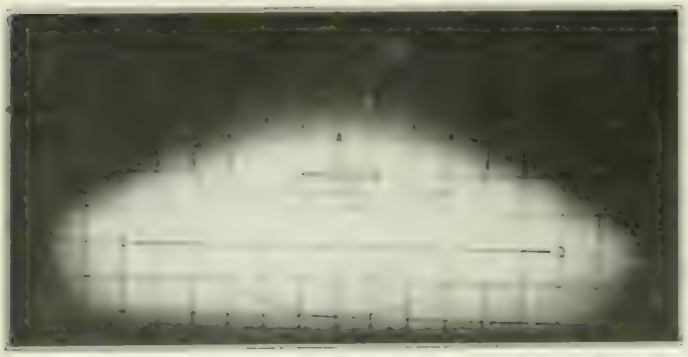
The Photograph from Which This Illustration Was Made Was Taken at an Angle To Emphasize the Prisms

assist in making adjustments. Obviously, inaccurate reflectors cannot be expected to give satisfactory results.

The upper central and right views of Fig. 3 show how the reflected rays change in direction when the light source is placed ahead and back of the focal-point. The corresponding lower views show that the beams are less concentrated than when the source of light is about the focal-point and, since the light is distributed over a larger area, the candlepower is correspondingly less.

The two views at the left of Fig. 4 show the effect

FIG. 6—LIGHT DISTRIBUTION PROVIDED BY ACCURATELY CONSTRUCTED HEAD-LAMP EQUIPPED WITH THE NON-FOCUSING LENSES SHOWN IN FIG. 5



head-lamp or the reflector alone, or by using simple horizontal prisms of uniform bending-power over the entire face of the lens. The advantage of horizontal prisms occurs when the lens is designed so that the light from different sections of the reflector is bent and spread by varying amounts to improve the distribution, as shown in the lower right corner of Fig. 4.

It is evident, from this discussion of the fundamental principles underlying the operation of the head-lamp, that it is a very sensitive device. The distances from the filament to the reflector and the lens are so short as compared with the distances ahead of the car to which the light is projected that satisfactory results cannot be expected with inaccurate or poorly adjusted equipment.

Even when the equipment is good, the problem of securing proper adjustment still remains. Greater simplicity will help in its solution. The proper adjustment of all devices in general use today necessitates both focusing and aiming. It appears impossible to eliminate the aiming adjustment; to design redirecting equipment that will eliminate the focusing adjustment is both possible and practicable.

Lens Design That Eliminates Focusing

A design of lens that, with accurate equipment, will compensate for commercial variations in the position of the filament in the lamp and at the same time distribute the light effectively in the beam is shown in Fig. 5. It takes advantage of the fact that rays reflected from a parabolic surface converge or diverge as the light source is moved ahead or back of the focal-point, as is illustrated in the upper central and right portion of Fig. 3. The light-rays passing through the middle zone are titled downward slightly and form the upper part of the beam. As the filament is moved forward or backward, the rays in this zone converge or diverge laterally and maintain the top, or cut-off, of the beam substantially at the level of the head-lamp. The rays of light from the upper and lower zones tend to rise or fall as the lamp is moved, but they are deflected downward sufficiently by prisms so that they will not rise above the top of the beam from the middle zone when the filament is moved forward or back of the focal-point through predetermined and relatively wide limits. Incidentally, beams from reflectors that are surfaces of revolution but not truly parabolic in contour ordinarily will have a sharper cut-off at the top with this design of lens than with others that spread the beams.

To illuminate the road-bed most effectively, the maximum intensity should be placed as near the top of the beam as possible, whence it will be projected farthest down the road. Since the eye accommodates itself rather slowly to changes of intensity, the candlepower should fall off toward the bottom and sides of the beam to illuminate the road-bed evenly and to eliminate the bright spots that reduce the visibility of points beyond them. These characteristics have been incorporated into the lens shown in Fig. 5, by spreading and bending the light in each zone by different amounts. The middle zone bends the light passing through it very slightly and the spreading effect is hardly more than is necessary to smooth the beam. The lower prism bends the light considerably more and spreads it sufficiently to illuminate the sides of the road near the car and assist in making turns. The upper zone has an intermediate spread and tilt. When focused to give the best results, the beam has the form shown in Fig. 7, from which it will be noted that its boundaries follow fairly closely the test stations that the Society has determined upon in specify-

ing desirable road illumination. The design is such that there is sufficient stray light above the horizontal to illuminate pedestrians, overhanging obstructions and similar objects.

This lens can be designed to compensate for variations of position of the filament of various magnitudes within the commercial limits ordinarily accepted in lamp manufacture. The distribution of light becomes less desirable as the tolerances are increased. The most satisfactory compromise between light distribution and accuracy in lamp assembling appears to result when the lens is designed to compensate for variations of 3/64 in. ahead or back of the focus; in other words, for the tolerances to which tipless precision lamps are now being manufactured.

The permissible axial variation of 3/64 in. to which these same tipless precision lamps are manufactured is also acceptable. Axial variations tend mainly to raise or lower the entire beam without seriously distorting it. They may be compensated for with a fair measure of success by aiming the head-lamps.

Constructional Features Demanding Attention.

Lamps should be uniform and efficient in performance throughout their life. They should have highly concentrated filaments to give the minimum beam-divergence. The filaments should be placed accurately with respect to the locking-pins and to the axis of the base to minimize beam distortion. They should not sag in service (See Fig. 8).

Sockets should grip the bases firmly and fit the reflector sleeves closely so that the lamps shall not be jarred out of adjustment when the car passes over rough spots in the road. The socket and the reflector axes should coincide. The electrical resistances at the contacts should be low to minimize the loss of light.

Reflectors should be highly efficient and should not warp or tarnish in service. Inaccurate contour causes glare and unsatisfactory road illumination (See Fig. 9).

Lenses should be free from hills and hollows caused by the careless polishing of the glass molds. Their design should be based on sound engineering principles.

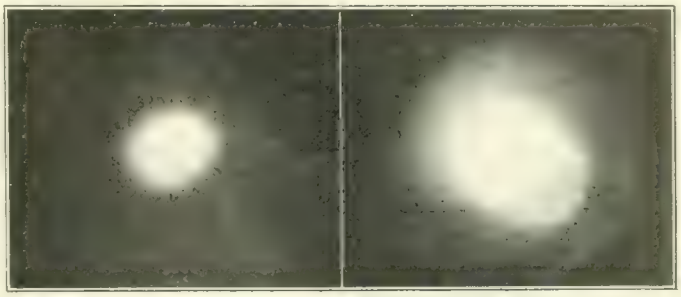


Fig. 9. How Inaccuracies in the Contour of Reflectors Frequently Render Otherwise Good Equipment Ineffective.

The View at the Left Shows the Cross-Section of the Beam from an Accurately Made Reflector, While That at the Right Is the Cross-Section of the Beam from a Reflector That Was Inaccurately Manufactured. Both Reflectors Were Taken from the Regular Production of the Two Factories and the Photographs Were Reduced to the Same Extent

Doors should be easy to remove and to replace. Means should be provided to prevent the lens from rotating.

Universal mountings should be provided to facilitate aiming. The importance of proper aiming cannot be overemphasized.

Adjustments should be carefully made before the car is delivered to the owner and simple but adequate instructions for readjusting should be given in the instruction book.

The fact that a few of the parts manufacturers are able to furnish equipment that will meet most of the requirements discussed above at little if any increase in price is proof that it is today commercially possible and practicable to attain the required standards of accuracy. Satisfactory performance, however, is unquestionably of sufficient importance to justify the small additional cost of thoroughly satisfactory equipment when it is necessary.

The use of devices that will obviate the necessity for focusing and that will leave to the motorist only the simpler adjustment of aiming should increase the number of cars with properly adjusted head-lamps and should assist materially in regaining the cooperation of car-owners in improving head-lamp conditions throughout the country.

FEDERAL AID ROAD CONSTRUCTION

FEDERAL aid road construction reached a new high water mark in 1922, when the mileage of new road added to the growing system of Government-aided highways exceeded 11,000 miles. The exact length was 11,374.7 miles. This was almost twice as much as the mileage constructed in 1921, the best previous year, which added only 5943 miles; and it was more than seven times as great as the mileage completed in the first 4 years of operation under the Federal Aid Road Act.

Federal Aid Projects Completed December, 1922, by Types of Construction

Type	Mileage Completed
Graded and Drained	3,286.4
Sand-Clay	2,235.1
Gravel	7,621.3
Water-Bound Macadam	473.4
Bituminous Macadam	666.4
Bituminous Concrete	681.8
Portland Cement Concrete	3,542.8
Brick	310.6
Bridges	31.4
Total	18,849.2

The total cost of the roads completed in 1922 was over $216,000,000, of which the Federal Government's contribution was more than $90,000,000. This record, both as to total cost and Federal aid payment, was nearly twice as great as the accumulated totals for the 6 preceding years.

The total of Federal funds appropriated up to the end of the year, less the deduction for administration, was $388,625,000. Of this amount, $139,227,437.80 had been paid for completed projects. An additional amount of $70,269,119.08 had been paid in the form of progress payments on projects under construction as part payment of the $149,663,762.92 allotted to such projects, a further sum of $49,984,248.44 had been allotted to definite projects that had not yet been placed under construction and a balance of $49,749,550.84 was entirely unobligated. Including the newly approved projects, projects for which plans were under way and all projects in the pre-construction stages the total mileage of projects initiated and approved for Federal aid and in various stages of completion or completed was 45,185.7 miles.

The table in the adjoining column shows that the mileage of gravel roads is the greatest.

The average cost of all types per mile, exclusive of bridges, for the whole period of operation is $16,800. For the year 1922 the cost was $18,500.—H. S. Fairbank in *The Constructor*.

Cooling Capacity of Automobile Radiators

By E. H. Lockwood[1]

Annual Meeting Paper *Illustrated with* Charts

FOLLOWING the presentation of this paper as printed in the January, 1923, issue of The Journal, additional data were used by Professor Lockwood to constitute a third part to the original paper, which is published herewith, together with the discussion both oral and written, that was induced at the Annual Meeting.

For the convenience of the members, an abstract of the complete paper follows; and the text of the additional part of the paper is then presented, preceding the discussion.

ABSTRACT

THE heat-dissipating properties of three types of radiator-cores have been investigated at the Mason Laboratory, Yale University. These include the fin-and-tube, the ribbon and the air-tube groups, so classified according to the flow of the water and the air. The ratio of the cooling surface to the volume is shown to be nearly the same in the fin-and-tube and the air-tube cores, while that of the ribbon core is somewhat greater. A formula is derived for computing the heat-transfer coefficient, which is defined as the number of heat units per hour that will pass from one square foot of surface per degree of temperature-difference between the air, and the water and is the key to radiator performance, as by it almost any desired information can be obtained. When the heat-transfer coefficients have been found for a sufficiently wide range of water and air-flows the cooling capacity of a radiator can be computed for any desired condition. In an appendix the fundamental and six derived formulas are given. These treat such topics as pump circulation, thermo-syphon circulation, limiting depth of core required, final temperature, weight of water-flow and the like. The results of applying the formulas to six cores that were selected as representative of the three main types are presented in a series of charts.

The cooling demand on the radiator when the engine is both idling and running at full load, are stated to be a maximum at a car-speed of 25 m.p.h. A new rule is offered for determining the size of radiator that consists of allowing 50 sq. in. of core-volume for each horsepower produced at a car-speed of 25 m.p.h. Confirming evidence is adduced from automobile tests at 25 different stations of automobiles, which show that the average for the whole group was 51 sq. in. of core-volume per horsepower developed at the above named speed.

The tests of pressure-loss have shown that loops for the thermo-syphon system are by all odds better than the spaghetti system and that their difference points perhaps the most of the thermo-tube and the other more fundamental temperature. The author's final conclusions are that the different types of core are equally good for cooling, and that the difference between thermo-syphon and pump cooling is not that of primary importance.

Radiator Capacity and Engine Horsepower

An interesting point in radiator-design is to find the car-speed at which the cooling ability of the radiator will be taxed most severely. The limiting speed is not the highest, because the horsepower falls off rapidly at high speeds; nor is it the lowest, because the fan helps out the radiator at low speeds. This discussion relates, of course, only to the full power while running in high gear.

The determining factors are the power-curve of the engine and the cooling-capacity of the radiator, both being laid out on the car-speed as the base line. An example is given in Fig. 6, where these curves are plotted for a well-known light six-cylinder engine, the radiator of which is known to give satisfactory cooling. The power-curve in the figure was taken from dynamometer tests at wide-open throttle. The cooling-capacity curve was computed from formulas given in the paper, in which the average values for ribbon cores were used. Conservative values were taken, such as a summer temperature of 80 deg. fahr., and a jacket-heat of 4000 B.t.u. per hr. per engine-hp. The latter figure is very liberal, since 3000 B.t.u., or even less is used frequently for this item.

It will be observed that the cooling-curve thus plotted cuts the power-curve in two points, and slopes in the same general direction. Where the horsepower-curve lies above the cooling-curve, it indicates deficiency of cooling. This is seen to be a maximum at about 25 m.p.h. on the car-speed scale, which is, accordingly, the speed sought; that is, the speed at which the radiator will be taxed most in cooling the engine. It follows, that if the radiator will just cool the engine at a speed of 25 m.p.h., it will have reserve capacity at either higher or lower speeds.

A simple and logical rule for radiator design is to proportion the core for a car-speed of 25 m.p.h., with a capacity equal to the maximum horsepower that the engine can develop at that speed. When this rule is applied to the engine of Fig. 6, it yields the result that 50 cu. in. of core is required for each horsepower, or 50 x 26 = 1300 cu. in. for the whole core.

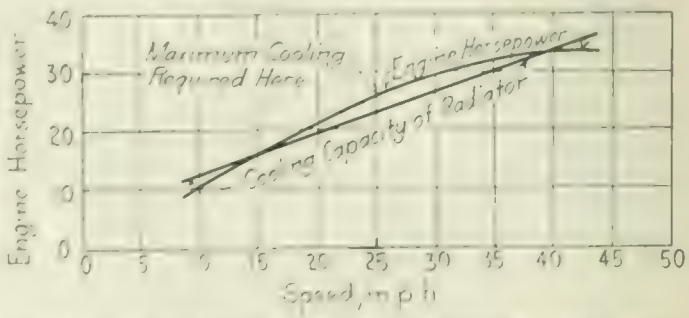


Diagram showing the Relation between Engine Horsepower and the Cooling Capacity of the Radiator for Various Sizes of Engine and Different Speeds

Radiator Sizes in Practice

If the conclusions drawn in the last section are true, it follows that the maximum cooling demands occur at a car-speed of 25 m.p.h., and that a core-volume of 50 cu. in. for each horsepower developed at that speed with open-throttle should cool the engine properly. It will now be in order to discover whether the radiators used in modern automobiles confirm these conclusions.

Considerable evidence is at hand bearing on this subject from the drum-dynamometer records at the Mason laboratory at Yale University. Upward of 100 vehicles have been subjected to power tests on the drums, representing more than 40 makes of automobile. In most cases, the radiator-core volume was measured and recorded at the time of the test. Excluding the cases where the records were incomplete as to core-type or size, 17 tests have been selected in which ribbon cores with pump circulation were used.

Some particulars of the 17 tests are recorded in Table 2. Column 1 contains a serial number for identification. The successive columns give piston-displacement, maximum horsepower developed at 25 m.p.h., total core-volume, core-volume per cubic inch of displacement and core-volume per maximum horsepower at the assigned speed. In addition to the figures in the body of the table, the average of each column is given on the bottom line. The figures in Column 6 represent the core-volume in proportion to horsepower. Although the figures vary from a minimum of 41 to a maximum of 71, the average is 51, or very nearly the value of 50 that was deduced in the last section for this type of core.

The core-volume can also be computed from the piston-displacement, as well as from the horsepower; and this rule may have occasional application. This rule can be deduced from the average at the bottom of Column 5, and may be stated thus: The core volume should be 5 cu. in. for each cubic inch of piston-displacement. There is a close relation between piston-displacement and horsepower, but it is better to use the latter in proportioning a radiator, if possible.

TABLE 2—DATA FOR RIBBON CORES WITH PUMP CIRCULATION

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Serial Number	Piston Displacement, Cu. In.	Maximum Power at 25 M.P.H. Hp.	Total Core Volume, Cu. In.	Core Volume per Cubic Inch of Displacement, Cu. In.	Core Volume per Maximum Horsepower, Cu. In.
100	224	22	1,440	6.4	65
112	424	45	2,300	5.4	51
125	228	30	1,330	5.7	44
143	224	23	1,110	5.0	48
147	340	34	1,390	4.1	41
162	247	28	1,940	7.8	69
173	226	21	1,500	6.6	71
176	298	28	1,590	5.3	57
179	171	17	850	5.0	50
193	525	54	2,250	4.3	42
197	361	32	1,620	4.5	51
212	191	23	1,010	5.3	44
214	289	28	1,360	4.7	49
222	242	25	1,200	5.0	48
224	572	42	2,270	4.0	54
228	242	27	1,280	5.5	48
229	525	41	2,210	4.2	54
Average..	312	31	1,570	5.0	51

TABLE 3—SUMMARY OF AVERAGES FOR FIN-AND-TUBE CORES AND THERMO-SYPHON SYSTEMS

Circulation System	Type of Core	Number of Examples	Cubic Inches per Horsepower
Pump	Ribbon....	17	51
	Fin and Tube...	6	43
	Both.....	23	47
Thermo-Syphon..	Ribbon....	3	55
	Fin and Tube...	5	55
	Both.....	8	55

Table 2 relates only to ribbon cores, but similar tables have been made for fin-and-tube cores, and for the thermo-syphon system of circulation. These tables will not be presented here, but a summary of their averages is given in Table 3. The results in Table 3 can be said to represent fairly the average practice in radiator sizes. They can be supplemented by facts drawn from individual tests.

The largest core-volume, relatively, was found in a four-cylinder, sleeve-valve engine, having 71 cu. in. per maximum horsepower at 25 m.p.h. The smallest core-volume was found in a V-type, eight-cylinder engine, having 33 cu. in. per maximum horsepower at 25 m.p.h. Curiously enough, both engines were cooled with fin-and-tube radiators with thermo-syphon circulation. The smaller radiator is said to be satisfactory, and the larger one is known to cool indefinitely at full power in low gear.

From the above results of the examination of the radiators used in various automobiles, it appears that radiators for the thermo-syphon system usually are made about 15 per cent larger than for pump circulation, and that the different types of core give about equal cooling.

Little attention has been paid in this paper to the engine fan as an adjunct to the cooling of the radiator. Without doubt, a powerful fan, well-housed-in to draw air from the core, will increase greatly the capacity of any radiator.

THE DISCUSSION

PROF. E. H. LOCKWOOD:—My paper naturally falls into three parts; first, the mathematical theory of radiator testing, as developed in the mechanical laboratory of Yale University in cooperation with local manufacturers; second, the application of the theory to several classes of radiator, using data obtained from a wind-tunnel apparatus, to determine what differences existed in the various types of core for heat dissipation; and third, an examination of existing automobiles to see whether the radiator supplied by the builders confirmed the conclusions drawn from the laboratory experiments. The third part was not included in the paper as printed in the January, 1923, issue of THE JOURNAL, as this material was collected after the paper was written. It was made possible by the records of the rear-wheel dynamometer in the Mason Laboratory, where many chassis tests have been conducted during the past 5 years, including measurements of the radiator as well as engine horsepower.

The mathematical theory is embodied in 11 formulas given in the Appendix. Formulas (3), (4) and (5), express the heat radiated by the core in different forms, depending on the quantity of water, the quantity of air or the extent of surface. By combining formulas (3), (4) and (5) and eliminating terms, formulas (6) and (7) are derived. Formula (6) is of importance, because it

gives the cooling capacity of the core with two troublesome variables, the exit temperatures of water and air, eliminated. The other quantities in formula (6) can be assumed or determined in advance without great difficulty. The airflow through the core can be computed by using formula (2), after measuring the free-air area and the velocity of the air through the free-air area by wind-tunnel experiment. The latter velocity can be expressed in terms equivalent to a given car-speed.

As the relation between car-speed and air velocity through the core is still apparently one of the unsettled points in radiator testing, a few words on this point are in order. At a given car speed in miles per hour, S, a pressure against a flat plate normal to the airflow, expressed in inches of water column, h, will be produced. The theoretical relation between the speed and the pressure in this case is expressed by $h = S^2$ 2070. In a specific example if the car speed is 25 m.p.h., the water-column pressure by the formula is 0.302 in. Duplication of this car-speed in the test apparatus will be accomplished by a total pressure difference on the opposite sides of the radiator equal to 0.302 in. of water column. The air velocity through the core is known in terms of the pressure difference; hence, it is known also in terms of car-speed.

A description of the test apparatus was omitted from the paper; hence a diagrammatic drawing is shown in Fig. 7. The radiator is sealed in an opening in the side

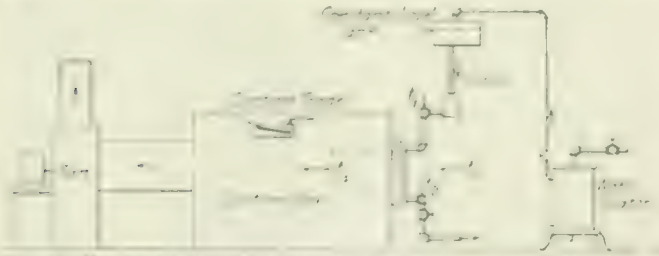


Fig. 7—Diagrammatic Drawing of the Apparatus Employed in Making the Radiator Tests Described in the Paper

of an air-tight chamber that, in turn, is connected to a suction fan. After the air has passed through the radiator, it is confined in a short tunnel for temperature measurement. The pressure difference is measured between the suction chamber and the room from which the entering air flows. The water supply is heated by a closed steam-coil heater; thence, it flows to an elevated tank where its level is maintained by a float and a valve. The water is metered by an orifice below the constant-head tank; thence, it flows through a pipe to the radiator. The head in the radiator is maintained by a needle-valve in the outlet pipe. The water temperatures are measured by mercurial thermometers immersed in the water pipes near the radiator. The loss of head in friction of the core and pipe connections is measured by gage glasses attached to the pipes leading to the radiator.

In using this apparatus to measure the heat-transfer coefficients, the procedure has been to select three orifices that, under the constant head, will give water-temperature drops of 15, 30 and 45 deg. fahr., approximately. In this way a proportionate amount of water-flow for each size of core will be obtained, covering a range from thermosyphon to moderate pump circulation. With each orifice in place, the fan speed is adjusted to give air-pressure differences of 0.20, 0.50 and 0.90 in. of water on opposite sides of the core, corresponding to car-speeds of 20, 33 and 44 m.p.h.

CHAIRMAN T. J. LITLE, JR.:—Is Professor Lockwood familiar with the design of radiators that are used in connection with the steam-cooling of automobile engines? Steam-cooling has been discussed at some length lately and I understand the radiator has to modified somewhat; some baffling is necessary. When an engine is cooled with steam, a slightly different problem is placed on the radiator than when it is cooled with water.

J. J. CUCURELLO:—The passages for the circulation of steam in the cellular-type core are so narrow that they are easily clogged by sediment in the system, so that in time the radiator as a whole would drop down in condensing capacity and burst and leak. The only type we found that gave good results was the fin-and-tube type, consisting of ⅜-in. outside-diameter tubes with relatively small fins, the projected area of which is possibly about 50 per cent of the total surface-area. The size of the fin was ¾-in. square, and the best results were secured when the fins were spaced about six to the inch. We are satisfied that the only type of core that will handle the steam-condensing proposition for automotive use is a core like that used at present in the condenser on a certain steam automobile.

Professor Lockwood's paper, as applied to the passenger car, motor truck and tractor, gives a direct method of computing radiator-core proportions when the heat-transfer coefficient, atmospheric temperature and other conditions are known. Theoretically, his formulas take into account all the variables affecting the ultimate results, but a question arises as to whether it is possible to obtain correct results with practically any size of core. Most test cores are made comparatively small to meet the laboratory-equipment limits of capacity and for convenience in handling, especially when a large number of cores is to be tested. Therefore, although the heat-transfer coefficients used for core sizes not differing in height by more than plus or minus 20 to 100 per cent of the test-core height are well within the limits of correctness, when we are called upon to more than treble the height of the test core, we may find that some types will not give the same results as others and as computed.

One of the drawbacks encountered is that, occasionally, the amount of water requisite to handle the heat is unable to pass through the core, thus upsetting the temperature-drop and the ultimate result. Another drawback is that, if the core is very high, we find that the water has suffered a large drop in temperature despite the rapidity of its flow, giving an abnormally cool condition at the bottom of the radiator, from which it is difficult to extract heat. It is apparent that, after we have determined the size of the core, we shall have another task confronting us, that of making it work.

We had an experience with a high airplane-radiator in which we had to divide the core into halves to reduce the water-temperature drop. We obtained the best results by running part of the water through the top half of the core and drawing it out from a tank vertically dividing the core halves; the remainder of the water from the engine was bypassed directly to the lower half of the core and thence it emptied into the bottom tank. In this way we were able to keep the radiator core at the bottom comparatively hot and efficient.

DR. H. C. DICKINSON:—Professor Lockwood's interesting paper gives data on radiator practice that should be of value as a guide to preliminary design. The practicability, however, of depending upon the final figures of 5 cu. in. of radiator per cubic inch of displacement, or 50 cu. in. per hp. is somewhat questionable, because the individual requirements of different engines and car designs may differ from this average value by amounts far too great to be neglected in practice. The author gives,

for instance, extreme figures of 41 and 71 cu. in. per hp., respectively, in two designs that were tested in the laboratory. It seems doubtful whether such differences are due merely to differences of judgment as to satisfactory cooling capacity or to actual differences in the capacities required. Radiators cost too much to be used too generously; on the other hand, overheating is too serious a defect to be tolerated. It seems more probable that some of the following factors are responsible for much of this difference:

(1) Engine design has much to do with the proportion of heat that goes to the exhaust. In fact, this proportion may vary from a minimum of about 60 per cent of the engine power to perhaps 150 per cent of it, at normal loads. While there are, probably, no such large differences between conventional passenger-car engines, the differences are by no means negligible

(2) The hood and the engine mounting determine the freedom of the circulation through the radiator; hence, to a considerable extent, its cooling capacity. In some car designs little provision is made for the exit of the air that enters through the radiator while, in other designs, the passage is not restricted; in still others, louvres in the hood probably produce a certain amount of suction that assists the fan in drawing air through the radiator

(3) Size, speed and design of the cooling-fan are important, as the author mentions, and it is more than likely that differences in the fan alone might modify the radiator requirement considerably

Statistical averages, such as are developed in this paper, are very important. The technique of securing reliable results in this manner is far too little developed and the author deserves much credit for the results he has obtained. There are some problems that can be attacked in no other way, as, for instance, the probable ton-mileage per gallon of fuel in service operation, or the demand of the average driver for any particular feature of car performance, such as acceleration.

N. S. DIAMANT:—Consider a radiator core, 20 in. high, 20 in. wide and 3 in. deep, or 20 x 20 x 3 = 1200 cu. in. Suppose that the total cooling or radiating surface of this core is 100 sq. ft., or 14,400 sq. in. Further, suppose that this core when tested at an air-velocity of 20 m.p.h. and a water-flow of 50 gal. per min., dissipates 1500 B.t.u. per min., with the average water-temperature equal to 190 deg. fahr. and the average air-temperature equal to 90 deg. fahr. Then for this core, the coefficient of heat-transfer will be 1500 divided by 100 sq. ft., divided by 100 deg. fahr. (= 190—90); that is, 0.15 B.t.u. per min. per deg. fahr. per sq. ft., or, 0.15 x 60 = 9.0 B.t.u. per hr. per deg. fahr. per sq. ft. This is the coefficient given by Professor Lockwood in Figs. 2 and 3.

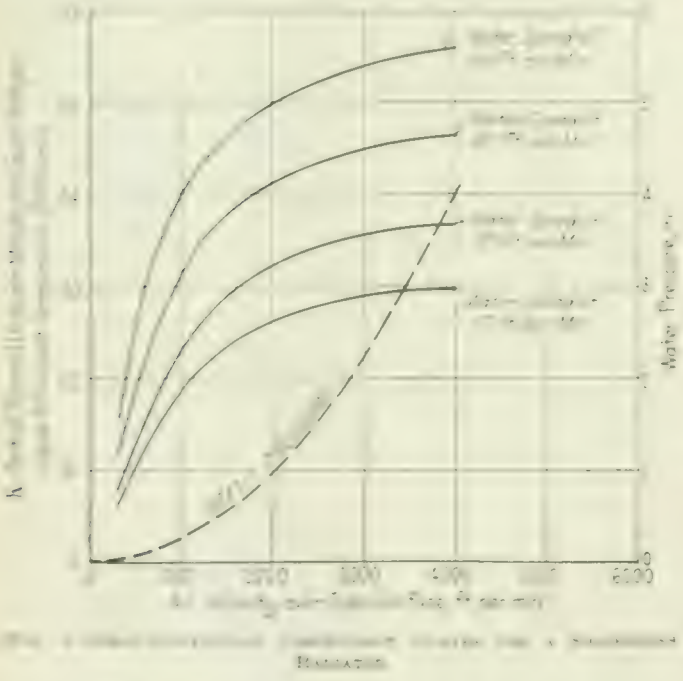
Suppose we want to compare with this radiator another one similar to it in every way except that it is 4 in. deep or 2 in. deep; what water-flow shall we use, 50 gal. per min. as before? Professor Lockwood tells us nothing about this important point. If the water-flow were proportional to the core-depth, then the proper abscissas for the curves given by him would have been gallons per minute per inch of depth of core. In any case, I hope it is clear that test results will be meaningless unless proper consideration is given to the relation between the water-flow and the depth of the core.

Professor Lockwood covers a range of water-flow of 1000 to 4000 lb. per hr. or, in the more usual units, about 17 to 67 lb. per min., or 2 to 8 gal. per min. The curves given in his paper are nearly, or at least roughly, straight lines, and thus, with many others, he seems to think or to give the impression that the cooling-capacity of a core is nearly proportional to the water-flow. This is wrong, as the excellent and creditable work done by the Bureau of Standards under Dr. H. C. Dickinson has shown that this is true for a water-flow up to 2 to 3 gal. per min. per in. of depth of core; but beyond this, increasing the water-flow does not appreciably increase the cooling-capacity of a core. I was rather surprised to find in the paper nothing with reference to this prevalent misunderstanding to which, apparently, the author also subscribes. I have not investigated this question as carefully as has the Bureau of Standards, but I have found in my work also that increasing the water-flow to more than 6 or 9 gal. per min. for a 3-in. core, and in proportion for other depths, does not increase the cooling-capacity or the heat-transfer coefficient of a given core.

Let us return to the example just given and try to compare it with the radiator-cores given by Professor Lockwood. As already stated, this radiator dissipates 1500 B.t.u. per min. per 100-deg. fahr. difference between the average water and air-temperature; that is, 1500 x 60 = 90,000 B.t.u. per hr. per 100 deg. fahr. is its cooling-capacity. Referring to Fig. 4, we find that 90,000 is on the chart; but how can we use Professor Lockwood's chart when we do not know what temperature-difference he has used. We used 100 deg. fahr. (= 190 — 90), but he may have used 100, 105, 95 or what not. The only reference is in the second paragraph under "Cooling Capacity Charts," where it is stated that the "water-temperatures were taken as 200 to 180 for pump-circulation, and 200 to 140 deg. fahr. for thermo-syphon circulation." The air-temperature was assumed to be 80 deg. fahr. Thus, it would appear that, in the chart, reproduced as Fig. 5, the temperature-differences were taken as 190 — 80 = 110 deg. fahr., and [(200 + 140)/2)] — 80 = 170 — 80 = 90 deg. fahr. for pump and thermo-syphon systems respectively.

Again, before we could use Fig. 4, or in fact before Fig. 4 can convey any intelligent meaning, it will be necessary that we know the size of the radiators. In the example given above, I took a core 20 in. high and 20 in. wide; in all my special testing work for several years I have adopted a standard core, 17 x 17 in. in size, because this is nearly equal to 2 sq. ft. of frontal area. If Professor Lockwood had given us the size of the radiators, including their depth, or if he had expressed cooling-capacity in British thermal units per minute per square foot of frontal area per certain number of degrees of temperature-difference between the water and the air; or if he had done anything equivalent, then Figs. 4 and 5 would have meant something. It is not possible to compare radiators on the basis of British thermal units per hour without giving the above information in one form or another.

Another point worthy of attention is the method of expressing airflow. Consider the same example given above and suppose that the air-velocity, as measured a few inches in front of the radiator, at a section 20 x 20 in., is 20 m.p.h. Assume that the airflow is fairly uniform, or that 20 m.p.h. is the average velocity. Then 20 x 880 x [(20 x20) / 144] x 0.075 =4890 x 0.075 =367 lb. per min. of airflow at the average temperature and barometric pressure. It has been found independently by the Bureau of Standards, by myself and by others that heat-transfer depends upon the mass-flow of air; the Bureau of Standards in its work has expressed this mass-flow in pounds per second per square foot of frontal area. This is the correct way to express mass-flow; however, in all my work I always have expressed it in miles



of cores made up of individual seamless copper tubes. In figuring the surface required to cool an engine properly with the thermo-syphon system, I have used a factor for core contents per horsepower that never exceeds 45. Our cores are giving extremely gratifying results in the cooling of a typical car of this class, namely, the Ford, by using a factor of 43 cu. in. per hp. These figures are based on the horsepower developed by the engine at a road speed of 25 m.p.h.; in the above case, very close to 15.

As I understand Professor Lockwood's charts, Figs. 3 and 4, he bases his calculations on the assumption, which is probably true for certain types of core, that car-speeds of 22 and 44 m.p.h. correspond to air-velocities through the core of 1500 and 3000 ft. per min., respectively. Professor Lockwood probably assumes that these figures are approximately correct for all types of core for the reason that, in Table 1, he finds that the free areas of all types are approximately equal. We have found in testing various cores that although the free area of any core, especially one of the fin-and-tube type, or of a certain ribbon cellular type, might be close to that of an individual tube type, yet the resistance to airflow of the first two types greatly exceeds that of the last. This is explained, to my mind, only by the fact that the eddy currents set up in the first two create an extra high resistance that we do not encounter in our core. Because of the lower resistance to airflow of our core, we are able to use a lower factor, or a higher heat-transfer coefficient, than is ordinarily used in common practice.

I believe that Professor Lockwood also makes the statement that the radiating surface might be considered proportional to the cubic displacement of an engine, or in other words, to its nominal horsepower. If this is so, I have never been able to explain satisfactorily why it is that we can cool such engines as the Ford, the Maxwell and the Chevrolet properly, all of which are syphoned by using a factor of 1¾ sq. ft. of radiating-surface per nominal horsepower, yet we find it necessary to use 2¼ sq. ft. per hp., or more, when figuring other cores that have a regular pump system. Perhaps it may be on account of the obstruction to the airflow in the large cores that is caused by the smaller clearance between the engine and its accessories and the hood, or louvres; but of this point I am not certain.

In conclusion, has Professor Lockwood ever reduced his calculations to the form of British thermal units dissipated per pound of core? To me this seems to be the logical procedure for, while it is admitted that a larger amount of radiating surface can be created in any core by the addition of various fins, inserts and the like, yet the type of core that will emerge superior will be represented by the core that can dissipate the largest number of heat units with the least weight.

L. C. JOSEPHS, JR.:—Professor Lockwood's paper is of particular interest to anyone connected with the motor-truck industry, as it will be a long time, if ever, before motor-truck builders will be able to get away from water-cooling. Laboratory tests of radiators are of considerable value, but great care must be taken in using these results to determine the probable performance of some new design. At the plant with which I am connected considerable work has been done along these lines. Many tests were made on small and on full-size sections of core mounted in a wind-tunnel, to determine the relative efficiency of the various designs of core; and a large amount of interesting data was found with regard to heat-convection coefficients. Figs. 8 to 10 show some of the results of this work.

The several points of view from which to judge the

efficiency of an automobile radiator in regard to the amount of heat removed are (*a*), per cubic foot occupied by the cooling system; (*b*), per horsepower consumed in air and water circulation; and (*c*), per pound of core material. The same type of core will not be the best when viewed from all three angles. When a cooling-system of a definite design is to be considered, a compromise among these three points of view will be necessary.

For this reason, we discontinued wind-tunnel tests some 2 years ago and have made all the tests since then on a test-stand on which a complete cooling-system is set up, exactly as it would be on a motor truck. The power is absorbed in a dynamometer and complete data can be secured as to temperature, water-circulation rate, air-circulation and the like. The test is made in a closed compartment so that any desired room-temperature can be secured, even as high as 135 deg. fahr., which corresponds to the conditions in the Imperial Valley in California. It is possible with this set-up to test not only radiator cores, as a part of a cooling-system, but the equally important items of pumps, fans, nature of the flow in the water-jackets, restrictions in the outlet of the air and many other seemingly minor points that actually have a great effect on a cooling-system. As a result of tests of this kind, our company has developed a very simple cooling-system recently, which, without boiling, will take care of the heat losses of the engine continuously at full load at any speed, at a still-air temperature from 100 to 110 deg. fahr.

In describing the air-cooling system developed by his company, C. P. Grimes made some similar claims, qualifying them by stating that a quantity of air should be blowing against the crankcase. It is interesting also to note that in the system that we have recently developed we have secured an air-temperature rise as great as 60 per cent of the air-water temperature-difference, which is equal to the results claimed by Mr. Grimes.

PROFESSOR LOCKWOOD:—Mr. Diamant's comments and criticisms are interesting, if only to prove that radiator testing is still an unorganized science, where fellow workers have difficulty in understanding each other. It would be a happy outcome of this discussion if a better agreement could be reached on some of the fundamentals of the subject.

Let us look first at Mr. Diamant's example of a core 20 x 20 x 3 in.; water-flow, 50 gal. per min.; air velocity 20 m.p.h.; and radiating surface 100 sq. ft. This core is

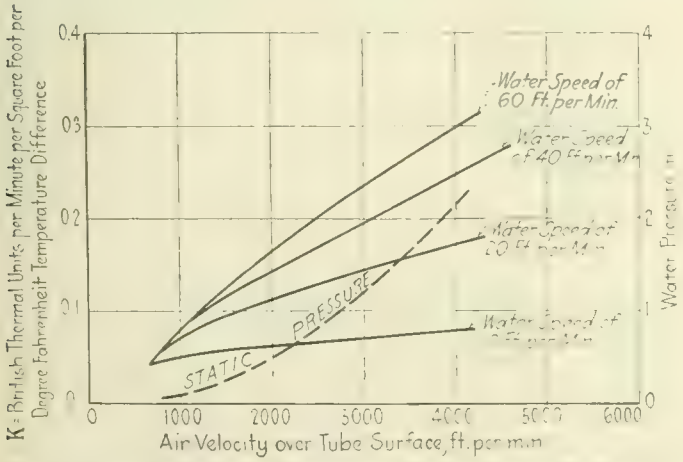


FIG. 9—HEAT-CONVECTION COEFFICIENT CURVES FOR A STREAMLINE TYPE RADIATOR IN WHICH THE AIR BLOWS AGAINST THE POINT OF THE STREAMLINE

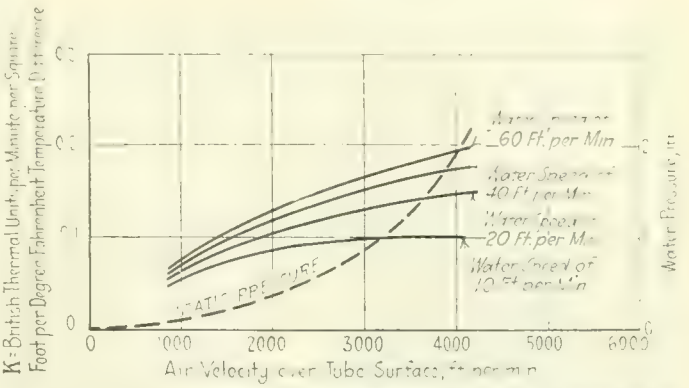


FIG. 10—HEAT-CONVECTION COEFFICIENT CURVES FOR A STREAMLINE TYPE RADIATOR IN WHICH THE AIR BLOWS AGAINST THE BLUNT END OF THE STREAMLINE

supposed to dissipate 1500 B.t.u. per min. with a mean water-temperature of 190 deg. fahr. and mean air-temperature of 90 deg. fahr., where the heat-transfer coefficient is found to be 9.0 B.t.u. per hr. per sq. ft. per deg. fahr.

To compare this radiator with another one similar to it in every way except that the depth is changed to 4 in., it will be necessary to make three new assumptions. First, the surface must be increased in proportion to the depth, or in the ratio of 4 to 3. Second, the water-flow must be increased to make the water temperature drop the same in both cores. Third, the heat-transfer coefficient will be slightly less for the deeper core. The claim that my paper gives no directions for water-flow in this case is not well taken, since the paragraph on Limiting Values of Core Depths states clearly that the water-flow is to be changed to produce the same temperature drop.

In applying formula (7) to this case, it is not necessary to know the rate of water-flow, as the temperature drop gives the same information. To illustrate this point and incidentally to show the utility of formula (7), the heat radiation for the 4-in. core will be computed with all other conditions unchanged. The surface will be increased from 100.0 to 133.3 sq. ft. The water-temperature drop will be 90,000 divided by 50 x 8 x 60, or 3.75 deg. fahr. The heat-transfer coefficient will be reduced from 9.0 to 8.5, an arbitrary figure in the lack of experimental data on this point. The air-flow will be computed from the 3-in. core, as this value must hold for the 4-in. core also. It will be assumed that the air velocity of 25 m.p.h. relates to the air approaching the radiator being reduced to 65 per cent of the original velocity when passing through the free-air area. With this velocity and a free-air area that is 70 per cent of the frontal area, the air-flow by formula (2) is found to be 9500 lb. per hr. The temperature of the air approaching the radiator will be assumed as the same for both. The air-temperature rise for the 3-in. core is 90,000 divided by 0.24 x 9500, or 39.5 deg. fahr. Accordingly, if the mean temperature is 90 deg. fahr., the entering temperature must be 90—19.7, or practically 70 deg. fahr.

Substituting the values in formula (7), the heat radiated is found to be 108,000 B.t.u. per hr. for the 4-in. core. Special attention is called to the facility with which this problem is solved by formula (7). The rate of water-flow was not required in formula (7), but it can now be computed by formula (3) as 29,000 lb. per hr., or 60 gal. per min., as compared with 50 gal. per min. for the 3-in. core. The final air-temperature

and be computed by formula 14, and is found to be 117.5 deg. fahr., or a temperature rise of 47.5 deg. fahr. above the initial temperature of 70 deg. fahr.

Passing from the problem just considered of water-flow in different radiators, let us consider the variation of flow in the same radiator and its effect on the heat transfer and the cooling capacity. The diagrams of my paper all show an increase of the heat transfer with the water-flow. Mr. Diamant criticises my finding and quotes the Bureau of Standards' statement that when the water-flow reaches a certain value of say 3 gal. per min. per in. of depth and a 1-ft. width of core, the heat transfer per degree becomes practically constant. There is, however, no real discrepancy between my results and those of the Bureau. My experiments have been carried out over the range of water-flow from 0.5 to 2.0 gal. per min. per in. of depth and a 1-ft. width of core. Over this range the heat transfer varies with the water-flow, as all experimenters know. These velocities were chosen as covering the ground between thermo-syphon on the one hand, and pump circulation on the other.

The falling off of heat transfer at low water-velocities has been charged to a lack of turbulence in the stream. A more natural explanation is that, at low velocities, the water chooses certain channels or tubes that offer least resistance, while the remaining channels have practically no circulation, hence rendering parts of the core inoperative, or nearly so.

In defense of Fig. 4, that Mr. Diamant has criticised, it may be sufficient to say that this diagram was prepared solely to compare different types of core with each other, to draw conclusions as to their value for cooling. For that reason the size of core used in the comparison was not given. On the other hand, Fig. 5 is intended to apply to one kind of core of any frontal area or depth within the limits stated. This diagram can be prepared for a given set of conditions, which are prescribed in advance. If different conditions are prescribed, a new diagram must be prepared. The conditions for Fig. 5 were a constant car-speed of 25 m.p.h., approaching air at 80 deg. fahr. water-circulation sufficient to cause a temperature drop of from 200 to 180 deg. fahr. for all sizes of core, and a good type of ribbon cellular core. The required water-flow for each core is given at the bottom of the chart in two different units. In attempting to solve the problem proposed by Mr. Diamant by this chart, the conditions differ so widely that the chart cannot be used.

In the matter of measuring air-flow, Mr. Diamant and I are far apart; indeed, we appear to have little common ground to stand on. For example, he refers to an hypothetical case of a 20 x 20-in. core with a given air velocity in front, for which he figures a mass-flow of 367 lb. per min. I have figured the air flow for the same data and arrive at the result of 170 lb. per min. Apparently, we are computing something different and are calling it by the same name. Mr. Diamant is plainly unable to understand my method of handling air velocity, and I confess to inability to understand how he uses mass-flow in his computations.

It is interesting to learn from Mr. Foisy that manufacturers of air-tube cellular-cores are obtaining satisfactory cooling with core volumes of 43 cu. in. per hp. at 25 m.p.h., and thermo-syphon circulation. Pump circulation is always assumed to give better cooling than thermo-syphon, yet the paradoxical fact exists that some engines cool better with thermo-syphon than others with a pump. The reason is to be found among the several things mentioned by Mr. Foisy, such as influence of the engine fan and the restrictions in the outlet of the air from under the hood. I have not made the comparison suggested by Mr. Foisy, of cooling capacity based on the weight of core used. This comparison is closely bound up with another of the same kind, the cooling capacity per cost of core.

Mr. Josephs has referred to a practical method of testing radiators used by his company, employing apparatus exactly equivalent to the truck on which the radiator will be used. As no mention was made of a separate blower, I assume that the engine fan circulated the air for cooling. We have made a few experiments on the rear-wheel dynamometer of a similar kind. With the rear wheels resting on the drums, the engine was run with a gradually increasing load until the radiator boiled, with no air cooling except that given by the fan. At the ordinary room temperature, the Ford radiator boiled with only 4 hp. on the engine. Under the same conditions, a Willys-Knight radiator cooled the engine when developing 28 hp. with no evidence of excessive heating. Both engines had thermo-syphon circulation.

Chairman Litle has mentioned the problem of steam cooling and how the radiator is dealt with in this case. It is safe to say that the heat dissipation with steam in the radiator is exactly similar to that for water. The steam-heated surfaces will be at a higher temperature than the water-heated surfaces; hence, they are more effective for heat removal. The thermal formulas for cooling capacity apply equally to water or steam.

Mr. Cucurello raises a point in radiator construction that is rarely mentioned, the limiting height of the core. He cites the case of an airplane radiator that was divided into two parts, with a water header supplying hot water to the top and the bottom parts, with a marked gain in cooling.

IMPURITIES IN STORAGE-BATTERY ELECTROLYTES

The importance of securing information concerning the effects of impurities in storage-battery electrolytes arises from the detrimental effect that many of them produce on the operating characteristics and life of the storage battery. Such information is necessary as a basis for the preparation of specifications covering sulphuric acid for use in batteries. A test method for measuring the rate of evolution of hydrogen gases was recently devised at the Bureau of Standards. The same method and apparatus have been employed in the present investigation with some modifications, and the effects of small amounts of iron, manganese, platinum and copper have been determined. It was found that the presence of 1 part in 10,000,000 of platinum in the electrolyte increases the local action at the negative plates 50 per cent; the effect of copper is much less, while the effect of iron is of unusual interest because of its accelerating action at the negative plates. Manganese deposits upon the positive plates in the form of manganese dioxide which covers the active material, closes the pores and causes a large amount of charging current to be wasted as gas. Work is being extended to include the effect of the other impurities that are frequently present in the electrolyte.

Two Kinds of Engineering

By F. E. Moskovics[1] INDIANA SECTION PAPER

MR. MOSKOVICS pays tribute to the motor-car engineer as being one of the great benefactors of humanity, and believes that two definite kinds of engineering, theoretical and empirical, are essential in designing, developing and building the truly great motor-car. He enlarges upon the requirements of empirical engineering and emphasizes the necessity for it, since empiricism is founded upon fact, experiment and experience, the last being inclusive of the essential element, time, without which no car can be proved great.

The service department is stated to be the only department in the automotive industry that can digest the empirical data that are obtainable from the actual experience of the public while operating cars and present it in an understandable form to the engineer, the agent being the service-manager, and a plea is made that he function as the eyes and ears of the automotive engineer.

I YIELD to no man in my conception of the magnitude and importance of the position of the engineer in our industry. What he has accomplished in the past, almost unaided by any historical data, is but a greater tribute to his genius and sheer ability. I believe that the motor-car engineer has been one of the greatest benefactors of humanity in general, and of our own generation in particular. Our present-day motor-car, with its combination of excellence and low price, is a tribute to him. The rise of the engineer as a leader in thought and development in all social endeavors has been extremely rapid, and it has come through sheer proof of his ability to analyze, deduce and conclude, and then put his findings into action to express energy in terms of fact.

The technical man alone is responsible for this early-stage development of the modern motor-car as a transportation unit. After all, this is only an elementary stage; the stage wherein it has been proved definitely that motor-cars can be made to operate over a fairly wide range of conditions and to perform their functions with a reasonable degree of consistency and of comfort to their users. The industry is rapidly approaching, if, indeed, it has not already reached, a more mature stage. And especially is this true on the mechanical side.

The reaping of the best rewards of this stage will require a different kind of engineering, and I have no hesitancy in saying that anything less than the very best results will reap no rewards. So, any remarks that follow, I beg will not be taken as a reflection upon the accomplishments of the engineer, but rather as suggestions as to how he can approach more easily and accomplish a little more fully the more wonderful things that open before him for tomorrow.

Future Engineering Accomplishment

As I view the mechanical structure of our industry, to design, develop and build the truly great motor-car, two definite kinds of engineering are essential. Nay, I would say absolutely imperative. The first I shall call technical. Theoretical, if you please. Here the technically educated and trained engineer is supreme and alone. Here the technician, the physicist, the metallurgist, the mathematician, the chemist, combine to design the coming car theoretically. But, after all is said and done, a car designed by the best of these elements is only an unbaked shell. No truly great motor-car was ever developed only on paper. I even venture the statement that no new engine was ever great during the first years of its existence. So, the technical man may design and experiment. He may drive and experiment with engines to his heart's content. But, until the car has gone through the varying crucible of the untrained, untried public's hands, it will never be really great. Theoretically, it may have every element of soundness. Metallurgically, it may be ideal. But until it has gone throught the millions of miles in the hands of the more or less unskilled Mr. and Mrs. General Public, it is untried and unfinished.

And here comes in my second kind of engineering, which I will call, for want of a better name, empirical engineering. The definition of an empiricism is a conclusion founded on fact, on experiment, on experience. The engineer must put his motor-car through the experiments and experience in the hands of Mr. Everybody; and, add to that, the always essential element without which no car can be proved great, time.

Under this form of engineering, consideration must be given to every possible factor; varying climatic and road conditions over the entire area in which the car is to be used. I submit to you that the confines of our own Country plus Canada offer in themselves a most fruitful field of study on this one subject. In the matter of the effect of altitude on both mixtures and pressures; the type of owner whom your particular car appeals to; the chauffeur in the case of a car of the higher grade; the maximum abuse the car can encounter, which will vary with its flexibility and speed; fuels, good, bad and indifferent; lubricants, their uses and abuses. After taking into consideration only these few points, without endeavoring to cover the field, deliberate for a moment upon maximum possible stresses the car can be subjected to by the greatest combination of all these elements. Empirical engineering must watch and study the cars in the hands and haunts of those great bosses of all of us, Mr. and Mrs. Ultimate Consumer. It must see, hear and understand and, when all the evidence is at hand, act intelligently.

Data for Empirical Engineering

Now the true data for this second kind of engineering cannot be supplied by the engineering department, due to the inherent limitations of its own peculiarities, its forms of organization and the fact that, after all, the engineer cannot make himself omniscient and cover the entire universe. Moreover, the engineer is entirely too personal in viewing the child of his brain, and cannot look fairly on the actions and results of that child when it gets out into the wide, cruel world.

In the modern motor-car factory, there is only one department that can digest this information properly and present it in understandable form to the engineer, the service department. I will not attempt here to analyze the meaning of service, but I will say that in the

[1] M.S.A.E.—Vice-president, Nordyke & Marmon Co., Inc., Indianapolis.

The Service Manager

He is the one whose duty it is to be in touch with the dealer's service departments throughout the Country. He it is who receives the individual complaints from the owners who come into contact with the well-equipped and poorly equipped service stations. The value of his work is measured by the accuracy and clearness with which he tabulates and presents to the engineering department the data he collects. He is charged with the grave responsibility of portraying just what the product is doing. He must interpret the public's approval or disapproval of the mechanical operation of the car; and, without abuse or personal rancor, distill the seething mass of information he secures into intelligible, usable data. This is a mighty problem, a great duty. It is second only in importance to the design of the car itself.

You will remember that there has always been grave argument as to who accomplished the greatest good for this Country; George Washington, the founder, the beginner, or Abraham Lincoln, the savior. I view the relations of the engineer and the service department in much the same light. The service manager must be diplomatic enough in the moments of stress, when a particular thing is going "bad," to present the case to the engineering department in purely mechanical terms. He can venture an opinion as to a cure, especially if it is the result of contact with a number of service-men. He can even arrange matters so that trusted service-men who come into direct contact with the owners will be brought into the factory for a confidential conference. All this can be done without casting any reflections on the engineering department, without any rancor or feeling. Indeed, it calls for a two-fold ability. The service department that does this as it can be done is invaluable to the engineering department, and no great engineer will ever refuse to welcome and use information obtained in this way.

If the service department functions in this manner, it will be the eyes and ears of the engineer. It will inform him as to where throughout the Country casing-head fuels are being used; where engine pounds are developed due to blended fuels; where crankcase-oil dilution and its attendant difficulties are most prevalent. The service department that does that to the greatest advantage will, in my opinion, perform its other more routine duties with little effort.

In a properly organized company, the chief executive will see that the service department has a voice in bringing these topics before a properly constituted authority, preferably the engineer. If, after enough repetitions have occurred to constitute a history, the mistakes have not been rectified, a clear channel should be established through which the service manager can present the difficulties to a higher authority. The right kind of service manager does not, I believe, need this channel, but will force the matter to an early conclusion.

Transportation Is the Commodity Sold

After all is said and done, we are selling transportation. We are not selling a mass of steel, aluminum, rubber, glass and leather called a motor-car. That is not what we are designing. It is the ability of this impersonal thing to perform acts of transportation that is important. And the service manager is the one man in the organization who can translate in substantial form what the engineer should know, whether the mechanism is delivering the form of transportation that our sales departments glibly promised to the ultimate consumer.

As the motor-car approaches more nearly the stage of mechanical perfection, this work becomes more and more important, because our public will become more and more critical; the little things we overlooked before become more and more aggravating, and can be eliminated only by the closest attention to detail and ascertaining the real results in the owner's hands. It is the irrefutability of basic facts that gives the modern engineer leadership.

ALUMINUM-ALLOY PISTONS

Since the introduction of aluminum alloy for pistons some 9 years ago, the two chief difficulties have been the development of a suitable alloy and a satisfactory design. The general use of metals, such as are now used in internal-combustion engines and pumps, has depended largely upon the coefficient of thermal expansion, and in connection with that of cast aluminum considerable trouble was met with before the engine got warmed-up. The yellow brasses have the temperature and clearing expansion a pretty near, that is well given for 2.0 thousandths [illegible] suggested by another authority and made use of in the aircraft engines in the United States.

The Bureau of Standards [illegible] pistons for gasoline engines with 14 per cent copper, 2.0 per cent nickel and 2.5 per cent magnesium. Due to low thermal conductivity, they gave an average temperature of 471 deg. fahr. about 12 tons per sq. in., compared with 7 tons for a 1-per cent copper alloy that was used to a very great extent some few years ago.

Cases occurring of burnt aluminum pistons show the upper side of the piston-head pitted like a sand-eaten casting, probably due to either faulty design or defective lubrication. Metallurgically, the fault appears to lie with the fusion and the migration of the copper-aluminum eutectic with the ultimate disintegration of the whole metal. To prevent the occurrence of large connected masses of copper-aluminum eutectic, the casting temperature must be kept as low as possible. Experiments show that the clearance should exceed by 50 per cent that of a cast-iron piston. The cast pistons are subjected to a temperature of about 716 deg. fahr. for at least 6 hr., but preferably 24, in order to bring the copper-aluminum compound, $CuAl_2$, into solid solution.—Extract from *The Metal Industry*.

Testing Materials for Automotive Parts[1]

By R. J. Allen[2] *Illustrated with* Photographs

In the production of any complicated machine such as the automobile considerable attention is paid to the dimensional inspection of all parts while but little attention, comparatively, is paid to the inspection of the quality of the material used other than to see that its surface is of the desired hardness and free from seams or cracks. The reason for this is two-fold: First, inaccurately machined parts, aside from being non-interchangeable, cause trouble in assembly and also prevent the smooth operation demanded by sales, while unsound or improperly heat-treated parts do not, in most cases, cause trouble until after they have been in service for some time; second, instruments for checking the dimensions of any machined surface have been developed to a much greater extent than have those for peering into the interior of metals, so that the inspection of the latter is necessarily more troublesome and uncertain.

The magnetic analysis and the X-ray offer possibilities for the future, but at present, aside from the simple surface-hardness test, all forms of physical tests are more or less destructive in nature and hence cannot be applied readily to the part intended for service. The usual practice therefore is to select representative samples from the lot of material received from the mill, make tests on these and assume the remainder of the stock to be of the same nature. Material accepted by these tests is then passed for use to be worked into forgings or machined parts. If the tests are numerous enough and the results uniformly good, it is perhaps logical to assume that the material is satisfactory, but subsequent to these tests carelessness on the part of the forge-man through improper hammering or excessive overheating, or on the part of the heat-treater may leave some of the pieces in such condition, not revealed by the final Brinell hardness test, that ultimate failure in service must result. The representative tests on the original stock therefore cannot be regarded as a true criterion of the finished part.

Prolongation Tests

To the company whose reputation is built on the continuity of service of each individual car over long periods of time without replacement or adjustment because of breakage or excessive wear it is essential that the soundness of each important or highly-stressed part be assured before it is passed for service. On vital parts, such as steering members, where failure may result in serious accident, this is doubly important. With present facilities the only reliable and at the same time practical way of obtaining this assurance is by the individual fracture-test. This, while not made on the material actually used in the part, can be carried so close to the actual part, with the aid of a properly attached prolongation, that the possibility of variation is indeed slight.

Fig. 1 shows a few of the parts of the Rolls-Royce chassis provided with test prolongations. These extensions are left undisturbed until the pieces have passed all stages of heat-treatment and final hardness inspection. Then they are nicked, broken off and examined. It will be noted that the prolongations are located so that when fractured they expose a transverse section of the central portion of the metal being used. Attention is called to the ball-end for the steering piece, a part machined from bar stock, with its double prolongation. The upper one reveals the depth and refinement of case, when fractured; the lower one, bent through an angle of 90 deg., reveals the ductility of the core.

Fig. 1—Method of Attaching Test Prolongations, Indicated by Arrows, to Highly Stressed Parts

From the appearance of the fracture one can tell whether the material is sound and in the structural condition desired, and also predict with considerable accuracy the results that would be obtained on a physical test. The prediction as to physical results, however, like the file test for hardness or the color observation for temperature, is not absolute, and recourse must be had frequently to some standard form of physical test, just as the feel of the file must be checked against the scleroscope and the color against the pyrometer.

Dynamic Tests

Excluding the hardness test, which is non-destructive, the forms of physical test against which fracture may be checked, vary. The tensile test is undoubtedly fundamental, but its static form of loading does not approximate with sufficient accuracy the condition under which most material is stressed in service; other forms of test, dynamic in nature, have therefore been devised to augment the tensile, each intended to check some particular condition or form of service stress. Among these may be mentioned the Izod impact, Upton-Lewis alternate-stress and the Stanton alternate-impact.

The Stanton machine, of English origin and until very recently relatively unknown in this country, has been used with satisfactory results by the company with which

[1] From an address delivered before the Providence, R. I., chapter of the American Society for Steel Treating.

[2] Metallurgist, Rolls-Royce of America, Inc., Springfield, Mass.

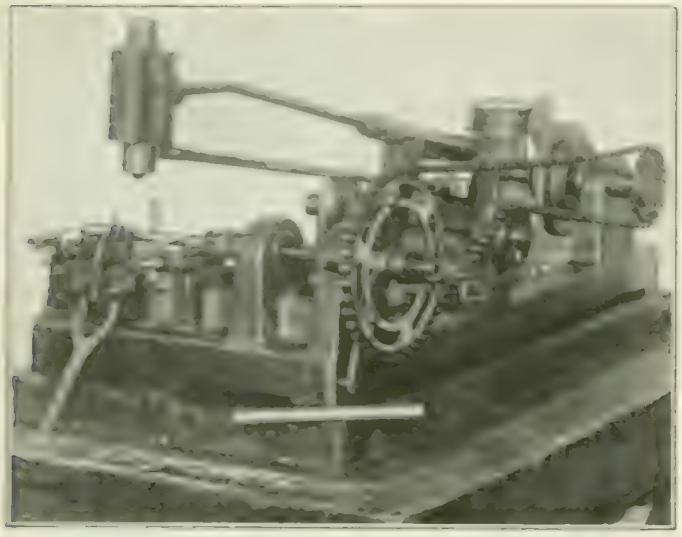


Fig. 1—The Stanton Automatic Impact Testing Machine

I am connected in conjunction with the tensile test on individual crankshafts, front axles, rear-axle tubes and on representative pieces selected from small batches of other parts, such as steering members, that in service are subjected to impact and reversed forms of stress. The machine is unique in that, first, the conditions of test are nearly similar to those encountered by the material in service, such as a front axle bounding over a rutty road; second, reliable test-results can be obtained in the short time of about 1 hr.; and, lastly, results can be duplicated with considerable accuracy. It is interesting to note that the principle of the test is being copied by some of the American instrument manufacturers; the machine is being offered for use in slightly modified forms. The machine is illustrated in Fig. 2.

Stanton Machine

The test piece, which is ½ in. in diameter, has a 0.05 in. square groove cut around its periphery near the center to localize the stresses. The piece, placed on two anvil supports 4½ in. apart, is set with the groove midway between the supports and directly under the 4-lb. hammer. The hammer is raised by a cam to the desired height, usually 2 in., from which it falls by gravitation onto the test-piece. Each time the hammer is elevated, which is at the rate of 90 times per min., the test-piece is rotated one-half turn so that successive blows are delivered on opposite sides. Failure, in the form of a fatigue, progresses from the opposite sides toward the center until finally the section paralleling a diameter becomes so reduced that it snaps off in tension. An automatic switch stops the machine when failure occurs and a recorder totals the number of blows. The number of blows obtained on the piece under test is compared with those previously obtained on other pieces of the same type of material which have stood up well in service, and judged accordingly.

Experience has shown that by purchasing steel from a reliable source where every precaution is taken to produce sound stock, by making suitable physical tests on representative specimens after forging and heat-treating, by Brinelling each piece and finally reading the individual test-fracture, one can hold failures to a negligible quantity.

THE WAR ON THE LOCOMOTIVE

In some of the complaints now being made by the railroad officials that the motor vehicles are robbing their lines of a large proportion of the short-haul freight and passenger traffic, the following extracts from an article with the above title that appeared in *McClure's Magazine* for March, 1903, are of interest:

> The number of passengers carried on American steam railroads has fallen off by over 12,000,000 in 7 years. The usual explanation is employed in the curious circumstance that people seem to be traveling longer distances. The average passenger haul in 1892 was 24.56 miles, in 1899 it was 27.09 miles.
>
> All regular passengers are not really traveling less frequently than they used to, nor are they journeying longer distances. More passengers by hundreds of millions are travelling than ever before, but the steam railroads are not carrying the increase. The growth in the length of the average passenger haul on those roads means, therefore, not traveling but the short-haul business, which is cheapest and most profitable to handle, which is cheapest and most profitable to handle, which is cheapest and most profitable to handle

Shoeing a Car with Low-Pressure Air

By J. E. Hale[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs and Diagrams

THE author describes the results of a deliberate attempt to make motor vehicles ride on air that is at a low pressure, through the usage of an air-cushion tire having greater carcass flexibility than is usual and by enlarging the size of the tire section so as to provide a greater area of contact between the tire and the pavement. The goal tried for was to increase the area of contact sufficiently so that air pressures ranging from 20 to 35 lb. per sq. in. could be employed in actual practice.

Fundamental conditions are considered first, followed by statements as to what advantages the air-cushion tires containing air at low pressure give to a car. The effects on car operation are presented at some length, inclusive of considerations regarding car speed, steering ability, front-wheel shimmy, traction, braking control, blow-outs, side-sway, and other factors of influence.

Durability and tire cost are treated in some detail, specific applications of air-cushion tires to automobiles are considered and a discussion of their desirability is invited. In conclusion, recommendations are made for a new tire-size nomenclature, in regard to oversizing and to tire-deflection limitation; and specific tire-size recommendations for air-cushion tires on stated makes of car are advocated in the Appendix and tabulated. Numerous illustrations and diagrams accompany the paper.

THERE are good reasons for believing that the automobile industry is on the threshold of the third great development in pneumatic-tire construction. The motor-car industry grew and expanded through its development years on square-woven fabric-tires of rather small cross-section. The art of building tires was new and our best constructions in those days were the small, stiff carcasses that naturally called for high air-pressures. Their shortcomings are too well remembered to need recalling, to say nothing of the range of sizes and the struggle for ascendancy between clinchers and straight-sides.

The employment of cord fabric in carcass construction was the second step in advance in pneumatic-tire structure. By virtue of this change in carcass construction, together with the realization of the importance of more ample sections, tire mileages were increased greatly, with a corresponding reduction in cost. There was not only a mileage increase, but the tires were much more reliable and not subject to such exasperating failures. It is possible that, with the consummation of the improvements and changes under development at present, the third step is ready to be taken. In this move we will take advantage of the cord construction that has proved its durability and reliability, combine this with a much larger section and a thinner wall and make it possible to ride on low-pressure air for the protection of the car and the greater comfort of the passengers, without any sacrifice in economy.

Someone has facetiously said that Goldberg, the cartoonist, in portraying doughnuts for wheels in his pictures, was the originator of the idea but, while he depicted large-section tires truly enough, the large section is not the whole story necessarily. On the other hand, of his own volition many an automobile owner has allowed his tires to be run under-inflated for his own personal comfort, explaining in a casual way that he did not intend to be shaken to pieces by the air pressures which the tire companies recommended, and that he was willing to sacrifice tire economy if necessary to secure this greater comfort; that is, he wanted to ride on low-pressure air. Also, a few cases are known of 6 or 7-in. thick-walled pneumatic truck-tires and truck rims having been applied to passenger cars and run at low pressure, notably by tire experimenters; this is, presumably, more in the nature of a stunt, since it does not appear that they had any serious thought of pushing the idea for actual commercial application to passenger cars.

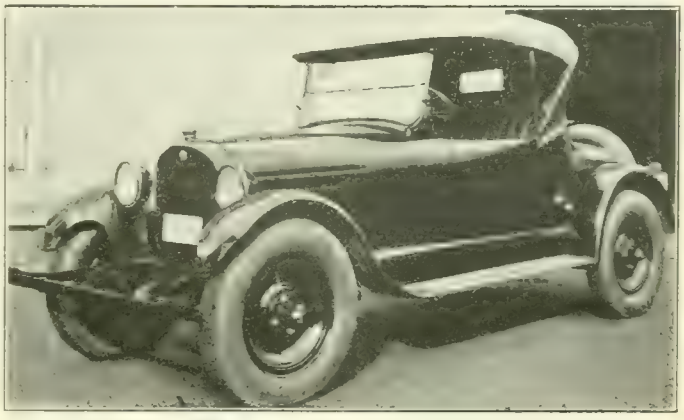


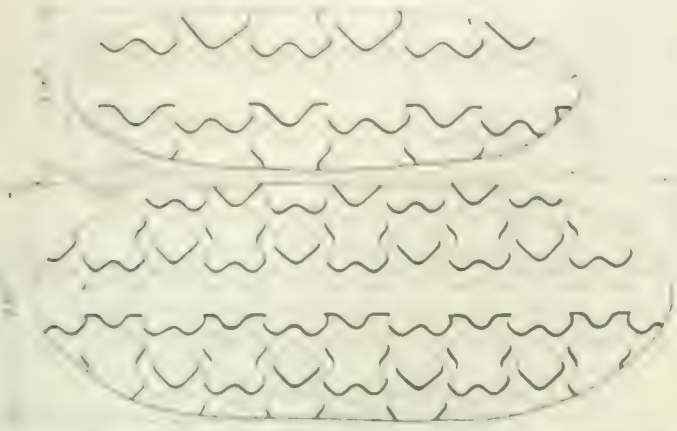
Fig. 1 Passenger Car Equipped with Four-Ply Air-Cushion Tires

This newest development, the air-cushion tire, is the result of a deliberate attempt to make riding on low-pressure air possible. It is the natural consequence of a strong conviction on my part that there ought to be a way to accomplish it that led the company I represent to take the bold step in going to an extreme and providing carcass flexibility and a section size sufficient to give the tire a larger area of contact with the pavement. Fig. 1 shows my car as it appeared when equipped with the original set of these tires in October, 1922; they were constructed with four plies of cord fabric, molded to 7¼-in. section, had a 20-in. wheel diameter and were inflated to a pressure of 18 lb. per sq. in.

Fundamentals Considered

The fundamentals of this movement are comparatively simple. If we are to have greater cushioning for comfort and protection against vibrations of the car, the combination of a low air-pressure and a large area of contact must be provided, and by employing such tire constructions that the tire durability will not be impaired. The goal aimed at was to increase the area of contact sufficiently so that air pressures ranging from 20 to 35 lb. per sq. in. could be employed in actual practice.

[1] M S A E.—Manager of the development department, Firestone Tire & Rubber Co., Akron, Ohio.



In a general way, the contact area of the tread with the road, expressed in square inches, multiplied by the internal air-pressure will give a figure that approximates the load resting on the tire. This is as it should be. It is evident that if a 1000-lb. load is to be imposed on the tire, and due to the limitation in the amount of vertical deflection not more than 20 sq. in. of contact can be obtained, it will require a 50-lb. per sq. in. pressure of air to carry the load. If, however, we can devise some way of increasing the area and still not exceed the proper degree of deflection; for instance, if we can increase the area to 50 sq. in., it will require very much less pressure; in this case a pressure of only 20 lb. per sq. in. is needed to carry the same load. Fig. 2 shows the tread imprint of a 7.30-in. air-cushion tire compared with that of the 33 x 5-in. high-pressure pneumatic-tire, each tire having been loaded to 1700 lb.; but with an air pressure of 35 lb. per sq. in. in the air-cushion tire and 65 lb. per sq. in. in the 33 x 5-in. tire. The vertical deflection of these two tires is shown in Figs. 3 and 4, which are drawn to the same scale to enable one to visualize the cross-sectional difference.

TABLE 1—HIGH-PRESSURE PNEUMATIC CORD-TIRES FOR PASSENGER CARS AND MOTOR TRUCKS

Size, In. Nominal	Size, In. Actual	Number of Plies	Maximum Load, Lb.	Maximum Permissible Deflection, Actual, In.	Maximum Permissible Deflection, Per Cent	Road Contact, Area, Sq. In.	Road Contact, Length, In.
Passenger-Car Tires							
3½	3.51	4	650	0.68	19.4	10.9	7.20
	3.70		700	0.83	22.4	11.8	7.85
4	4.40	6	1,000	0.81	18.4	17.0	8.90
4½	4.95	6	1,250	0.90	18.1	21.4	9.45
5	5.80	8	1,700	0.95	16.3	26.3	10.00
Pneumatic Truck-Tires							
6	6.60	8	2,200	0.86	13.0	36.7	9.00
7	7.70	10	3,000	0.92	12.0	45.8	9.60
8	8.80	12	4,000	0.97	11.0	54.4	10.08
9	9.90	14	5,000	0.99	10.0	67.0	11.20
10	11.00	16	6,000	1.10	10.0	79.5	10.35

One of the fundamental conditions of conservative tire use that we recognize is the limitation of the actual vertical deflection of the tire expressed as a percentage relation of the sectional diameter. It has been found that if this percentage of deflection is exceeded, the tires are likely to fail prematurely from two causes: First, tread separation and ply separation are likely to be excessive; second, the flexing localizes half-way up the side-wall and may cause fabric failure on the inside plies. It can be appreciated readily that, in the case of a thick-walled tire, the destructive effect of this flexing will be much more pronounced than in the case of a thin-walled tire. But, if we use low-pressure air, the bursting stresses on the carcass are low enough so that only a few plies are necessary and this, in turn, makes it possible to increase the deflection percentage. Table 1 lists the percentage

TABLE 2—AIR-CUSHION TIRES FOR PASSENGER CARS

Size, In. Nominal	Size, In. Actual	Number of Plies	Maximum Load, Lb.	Maximum Permissible Deflection, Actual, In.	Maximum Permissible Deflection, Per Cent	Road Contact, Area, Sq. In.	Road Contact, Length, In.
4.40	4.40	2 or 4	750	1.01	23	20.2	8.90
5.25	5.25	4	1,000	1.21	23	28.5	9.93
6.20	6.20	4 or 6	1,300	1.42	23	36.7	10.70
7.30	7.30	4 or 6	1,700	1.68	23	48.3	12.50

deflection limitations of high-pressure pneumatics; also, other fundamentals for comparisons to be referred to later.

Our tentative air-cushion-tire schedule offers four section sizes for passenger-car use, each size to be made of no more than six plies, constructed so as to permit their normal use with pressures between 20 and 35 lb. per sq. in. and to be used on rims the width of which is approximately 45 per cent of the tire section. Table 2 shows figures comparative to those of the high-pressure pneumatic-tire.

What Air-Cushion Tires Do For a Car

As to the effect that these tires have on the riding of the car, the first reaction to the occupants is the greater degree of comfort. Road-surface irregularities are toned-down and, in most cases, obliterated. Of course, the "ups-and-downs" in the road are still there and the car goes up and down with them, but everything is cushioned so that there are no sharp shocks or jolts; one does not need to watch the road to put his body in tense condition to get over the rough places, nor to be worried about being tossed up from the seat. Furthermore, the driver does not need to pick out all the good places in a rough road, because it makes little or no difference whether he takes them in or not.

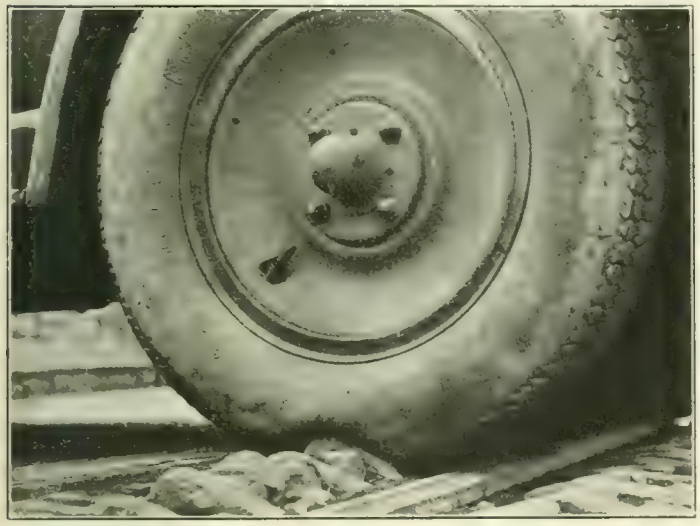


Fig. 5—A 7.30 Air-Cushion Tire with an Inflation-Pressure of 18 Lb. Absorbing the Inequality in the Road Surface Due to Heaved-Up Brick

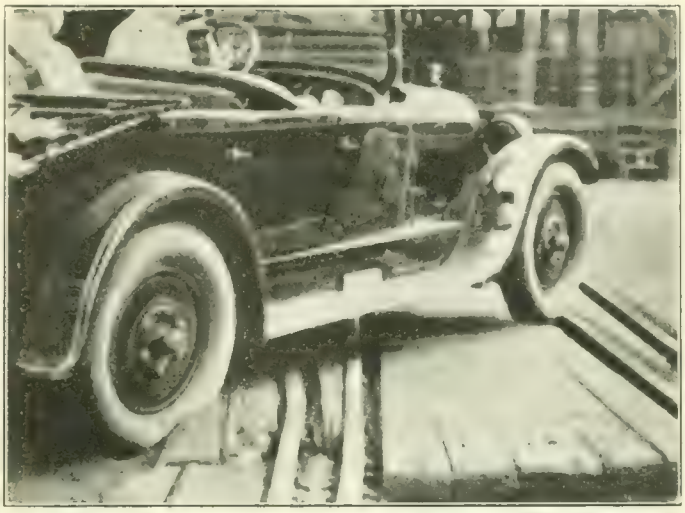


Fig. 6—Car Equipped with Air-Cushion Tires Passing over a Railroad Crossing

It is remarkable how a car equipped with 7.30-in. tires will negotiate a frozen road. As an extreme example, I

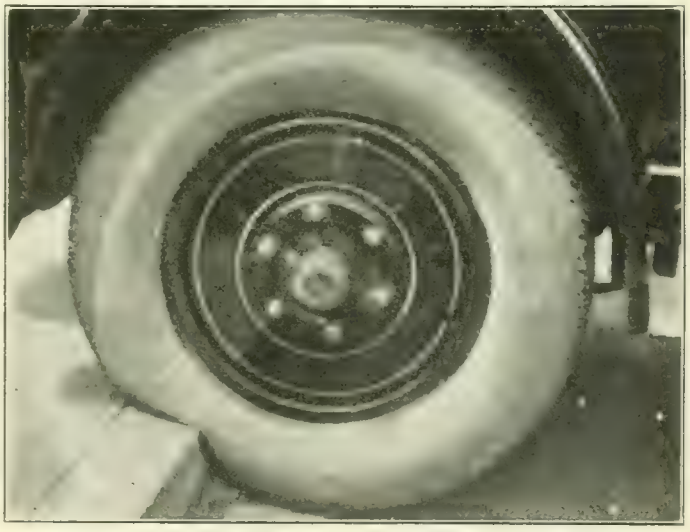


Fig. 7—How Air-Cushion Tires React against the Curb

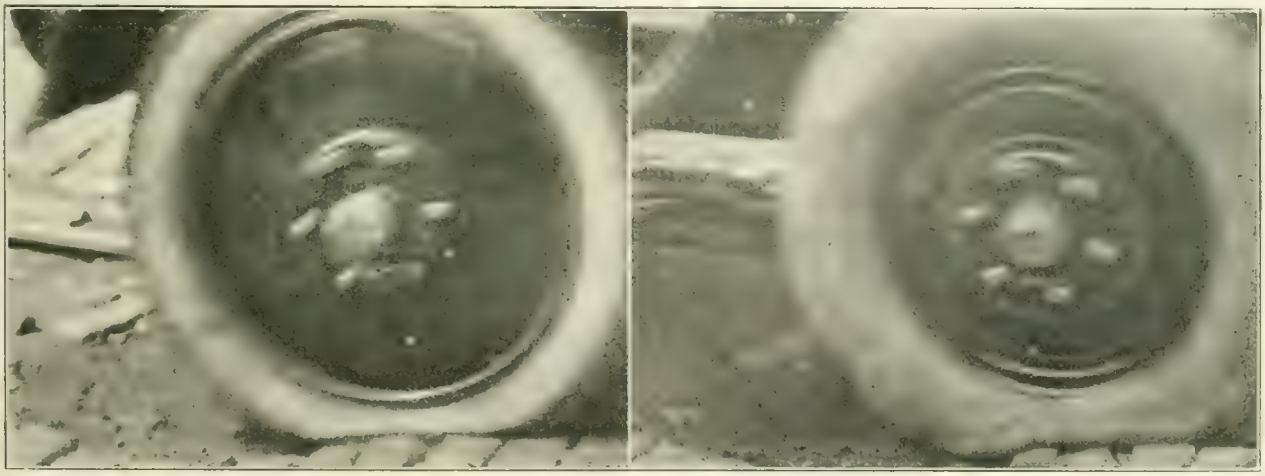


Fig. 8—Comparative Actions of a High-Pressure Pneumatic Tire (at the Left) and an Air-Cushion Tire (at the Right) Rolling Out of the Same Chuck-Hole

of tires that has no prospect of being commercially applicable. I believe we have reasonable answers for all of the practical operating aspects that arise.

Of questions on the various phases of practical car-operation, probably the most frequent is in regard to fuel consumption. In general, the air-cushion tires cause neither more nor less fuel to be consumed than do the high-pressure pneumatics. On actual fuel-consumption, a number of private owners have found that, by keeping account of the fuel used, they noticed a slightly greater mileage per gallon with air-cushion tires. Our most authoritative information, however, is derived from our observations on six taxicabs that ran a total of 20,000 miles during April, 1923, on 7.30-in. air-cushion tires; the fuel consumption averaged 13.5 miles per gal. This compares with a fuel consumption of 12.6 miles per gal. for a larger number of similar cabs that covered many times that amount of mileage on 33 x 4½-in. six-ply tires having an air pressure of 70 lb. per sq. in.

From the viewpoint of fuel economy, so far as tire technique is concerned, it appears that, in the case of the regular pneumatic tires with a smaller tread-contact, it is the internal carcass-friction rather than the tread rolling-resistance that absorbs energy. On the other hand, in the case of the air-cushion tires, the carcass being so thin as to have practically negligible carcass friction, the large area of contact occasions a much greater degree of road friction than in the case of the regular pneumatic tires, and it is probable that these effects would just about balance each other in the two classes of tire. With air-cushion tires, the cars coast just as freely and accelerate practically in the same degree as with high-pressure pneumatic-tires.

Fig. 10 shows the acceleration and coasting observations made on a car equipped alternately with 7.30-in. air-cushion tires having an air pressure of 25 to 28 lb. per sq. in. and with 33 x 4½-in. tires having an air pressure of 50 to 55 lb. per sq. in. The comparative tests were made without disturbing the brakes or bearing adjustments, since the wheel changes were made simply by switching disc wheels that are demountable at the hub.

Effects on Speed and Steering

The question has been raised as to whether, with air-cushion tires, the top speed will be cut down; that is, speeds of 60 m.p.h. and upward. While the evidence is not positive, the indications are that there may be a slight difference. Very likely, any appreciable slackening of these higher speeds can be attributed to the windage resistance of the tire. Unquestionably, tires with such large section covered with non-skid projections would make this a notable factor.

The question next frequently raised is in regard to how the steering is affected. This is perfectly natural, because most drivers have discovered that, when the front tires are soft, there is a slightly increased resistance to steering. From laboratory tests, we have found the area of contact of the air-cushion tires with the road surface to be about twice that of the high-pressure pneumatic tires, and under these conditions one can detect a slight difference in turning the wheel. In ordinary driving this effect is of such minor consequence that it cannot be considered a serious handicap. However, we find that, when the car is in close quarters, such as being parked by a curb, it is more difficult to pull the wheels around when the car has little or no headway.

In some cases the larger tires actually favor the steering. For instance, on streets having trolley-lines,

the front wheels are not deflected at all in making a cross-over from one side of the street to the other, even though the angle at which the car makes the crossing over the rails be the next thing to parallel driving. Another favorable feature is that, when dropping into chuck-holes or off the edge of the pavement, the reaction tending to deflect the car is much less pronounced. In fact, in the latter case, the control is infinitely better in regaining the pavement. It seems to me very probable that as car designers study the problem of fitting air-cushion tires to their different models, changes in steering-gear may be entirely plausible to compensate for any minor effects introduced by the tires.

A reference to the steering-gear brings to mind our

FIG. 9—TWO SIMILAR CARS ON A ROUGH DIRT ROAD SHOWING HOW THE OCCUPANTS OF THE CAR AT THE LEFT, WHICH IS EQUIPPED WITH HIGH-PRESSURE PNEUMATIC TIRES, ARE THROWN UP FROM THEIR SEATS, WHILE THOSE IN THE CAR AT THE RIGHT, WHICH IS EQUIPPED WITH AIR-CUSHION TIRES, RIDE IN COMFORT

unsolved mystery, the front-wheel shimmy. This has been observed and commented upon by certain car engineers in connection with the application of air-cushion tires. Just how far we should go in assigning the cause of this front-wheel shimmy to the application of the large-section low-pressure tires is not clear. I have encountered some cases of front-wheel shimmy on both high-pressure and low-pressure pneumatic tires and, in each case, the trouble has been taken care of by such methods of adjustment and replacing of the parts as the ordinary repair-shop has at its command. However, judging from the prominence that the subject of front-wheel shimmy has been given from a design point of view, it is not unlikely that the low air-pressure may be a factor that will justify the industry in considering it a joint problem for the tire and the car engineers to solve.

TRACTION AND BRAKING CONTROL

The traction and braking control of the car in driving is probably of equal importance with the fuel consumption and the ease of steering. I have not found any way to make comparative measurements of this effect, but can report my own experience which checks with that of every other user of the properly designed air-cushion tires. On wet pavements, with the brakes equalized properly, I have tried every way that I could think of to make my car skid but, so far, the only thing which happens is that the car stops. In the most ticklish traffic

TABLE 3—DISTANCE THE WHEEL DROPS WHEN THE TIRE BECOMES DEFLATED

Air-Cushion Tires		Pneumatic Tires	
Size, In.	Wheel Drop, In.	Size, In.	Wheel Drop, In.
4.40	2⅜	3½ (Clincher)	1⅞
5.25	2 15/16	4	2⅜
6.20	3⅜	4½	2⅞
7.30	4¾	5	3⅞

I have no fear about what I can do in an emergency. The large area of contact, with the greatly increased linear total of non-skid edges that gives a squeegee effect, undoubtedly is the combination that gives such excellent non-skid results.

In contrast to wood block or asphalt are cases of uneven pavement surfaces where the actual area and the button-edge contact is cut down by the road-surface irregularities. In the case of the air-cushion tires, the area is so large and the carcass is so flexible that it folds and rolls over the dips and hollows in the road surface so as to maintain a uniformly large area of contact at all times. This is not true in the case of the high-pressure tires, which are inflated so hard that they lose a great amount of their contact; the result is that the air-cushion tires hold much better on rough pavements. On snow and ice, the control of the car with air-cushion tires is noticeably better than with high-pressure pneumatic tires. This is true particularly in eliminating the tendency to skid sidewise in applying the brakes and rounding corners. In applying the brakes for a quick stop, one has to be very cautious lest the wheels become locked and, should this happen, the result is much the same as with the regular pneumatic tires.

Since front-wheel brakes are being considered so seriously by designers, I think they will do well to investigate thoroughly the capacity of air-cushion tires to control the car. From this point of view, it may be that this new type of tire offers sufficient improvement in braking control to obviate the necessity for front-wheel brakes.

TIRE BLOW-OUTS

The question of danger from a flat tire has come up. If one were driving at 40 to 45 m.p.h. and had a blow-out on the right front tire, what would happen? We are not in a position to make any very positive assertions on this

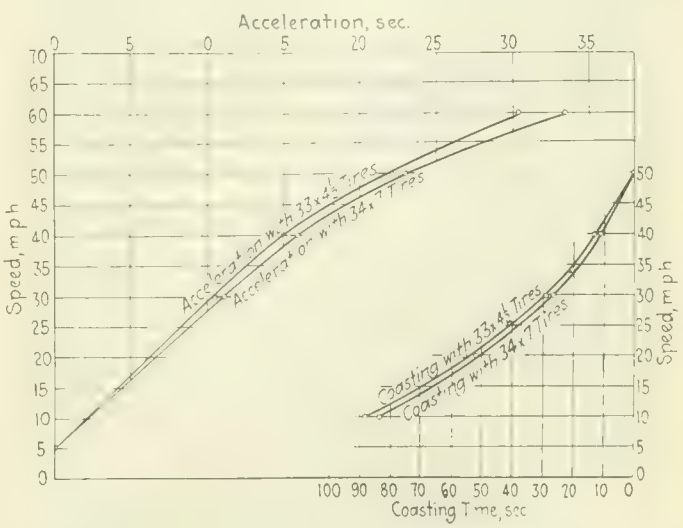

Acceleration, sec.
0 5 10 15 20 25 30 35
Speed, m.p.h.
Acceleration with 33x4½ Tires
Acceleration with 34x7 Tires
Coasting with 33x4½ Tires
Coasting with 34x7 Tires
100 90 80 70 60 50 40 30 20 10 0
Coasting Time, sec

FIG. 10—RESULTS OF ACCELERATION AND COASTING TESTS MADE ON A PASSENGER CAR EQUIPPED ALTERNATELY WITH 34 X 7-IN. (SIZE 7.30) AIR-CUSHION TIRES HAVING INFLATION-PRESSURES OF FROM 25 TO 28 LB. PER SQ. IN. AND 33 X 4½-IN. PNEUMATIC TIRES HAVING AN INFLATION-PRESSURE OF FROM 50 TO 55 LB. PER SQ. IN.

point, as may two blow-outs have occurred in all our testing experience. These occurred on a test car when the car was traveling about 50 m.p.h., the test-car driver states that it did not in any way cause him to lose control of the car or cause it to display any tendency to become unmanageable. We tried the experiment of producing a flat tire on the right front wheel of a test car having 7.30-in. air-cushion tires. Starting inflated, but with the inner tube valve-cores loosened to deflate the tire rapidly, we ran along at between 35 to 40 m.p.h. for a considerable distance after the tire was entirely deflated. We found it was necessary for the observer to step out on the running-board and actually look at the tire to be sure that it had become fully deflated; the driver found that he could take his hands off of the steering-wheel without producing any tendency to give trouble. This brings up the question of how great the drop is when the tire becomes deflated. Table 3 gives the figures showing the difference between the condition of full inflation and that of a flat tire.

Side-Sway

Some people are apprehensive lest the side-sway be objectionable.. This, in my opinion, is a point of view. I presume that a little more side-sway can be detected and

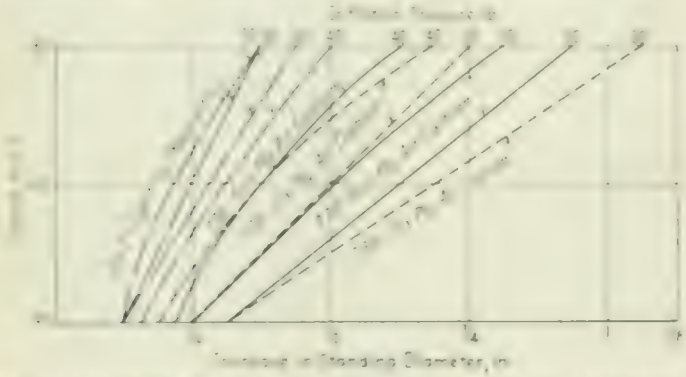


Fig. 11—Curves Showing the Increase in Standing Diameter of Low-Pressure Tires due to Centrifugal Force

measured with the air-cushion tires than with the high-pressure pneumatic tires; but it is my observation that, after becoming accustomed to the car, all thought about this feature disappears from the mind.

Centrifugal force deforms the cross-section of the tire, changing it from a substantially circular to an elliptical shape. The standing diameter is increased and the section diameter is diminished. The figures given in Fig. 11 were obtained simply by revolving the tire on a shaft and measuring with an indicator that was arranged to roll against the tread.

Another feature of control in driving is the new attitude on the part of the driver toward the roadway ahead of him, particularly if he does much driving after dark. He soon finds that whereas formerly he slowed-down or steered for the smoothest places in the street as a matter of course, this is not necessary with air-cushion tires. Of course, the very worst chuck-holes ought be avoided, but the driver soon learns that he need not slow up for rough spots, as he can take them without checking speed.

While it is apparent that the car can be driven much faster over the average highways as we find them with almost complete elimination of vibration, I am wondering whether this higher average speed may not lead to more or less serious troubles from another source. Will the powerplant and the transmission system withstand this higher average speed without suffering damage? Naturally, the conclusions on this point will need to be drawn by those skilled in observing such things and particularly by making direct comparisons with tires on the old equipment. It is my opinion that the increased speed will amount to somewhere between 10 and 30 per cent.

Galloping and Front-Wheel Toe-In

For some reason that is not very clear to me, cars equipped with air-cushion tires develop a violent galloping when they are not equipped with shock-absorbers. This is so noticeable that I can predict disappointment to any one equipping a car without the use of shock-absorbers. Possibly spring designers can furnish some explanation for this situation.

At present, it appears that the amount of gather or toe-in on the front wheels will have to be adjusted very delicately to prevent the excessive wear that appears with improper alignment. Our observations point clearly to the fact that air-cushion tires are more sensitive to improper alignment than are the high-pressure pneumatic tires.

Two features of car operation that register against air-cushion tires are their mud-splashing and dust-raising propensities. The larger-section tires with the greater area of contact spatter mud much more than any other tires heretofore brought out and, as for dust-raising on country roads, it is terrible. I believe that a motor-truck convoy could not raise more dust in traveling along a dry country road in summer than my own car raises. While this may be a minor point, it may develop into an objection.

Durability and Tire Cost

All our development work on air-cushion tires has been carried out under actual road-test conditions. To date, we have run a total of 850,000 tire-miles under test observations, and evidence points to average mileages at least as high as those enjoyed with regular pneumatic tires. The character of the failures unquestionably will be somewhat different. For instance, ply separation and tread separation will be minimized in air-cushion tires and, with these eliminated, the most prominent troubles will be fabric breaks in the carcass; also, punctures and rapid tread-wear on the front wheels when they are not aligned properly. Many people have questioned whether, with such a thin tire, punctures will not be sufficiently numerous to be of considerable annoyance. There are no grounds for concern on this score. In 50,000 car-miles of operation of our test fleet there were seven punctures, and in 100,000 miles of operation in taxicab service there was an average of one puncture for each 3700 taxicab-miles. The explanation is found in the fact that the tire, being not so taut and hard and drum-like, yields rather than becomes pierced by the puncturing object.

The light carcass-structure necessary in these tires also raises the question as to whether they have the stamina to withstand the rough usage to which the heavier cars are often put. A large measure of our road-testing development was on tires of the four-ply construction. Their performance under test conditions is repeatedly showing great ruggedness. One of these four-ply 7.30-in. test-tires gave out after having worn through the breaker and three of the four plies, as shown in Fig. 12. The interesting point is that it continued to run on this single ply for a considerable distance before finally blowing-out by bursting open at this point, as can be seen clearly in Fig. 12. When one considers that this was on the front wheel of one of our heaviest cars, which was touring in

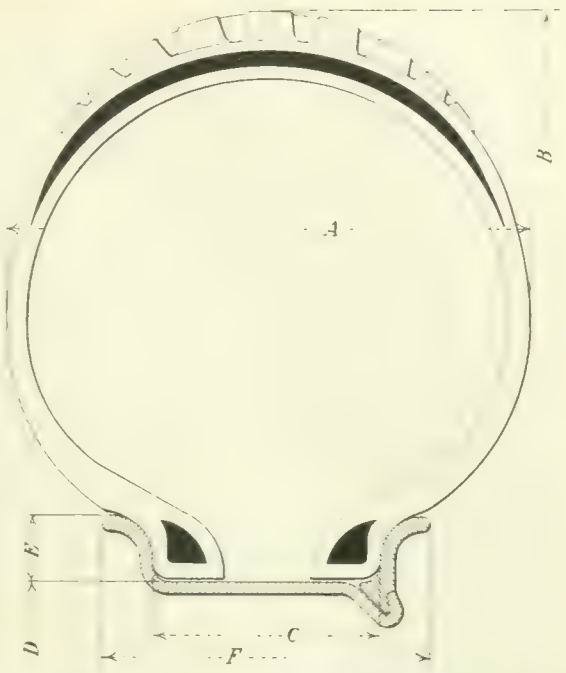
the South, it emphasizes the part that low inflation-pressure plays in making the casing so soft and yielding that the destructive reaction of ordinary driving largely is eliminated. In other words, no part of the tire is subject to high intensity of stress at any one point, which is contrary to the condition that applies to the high-pressure pneumatic tires. There is no doubt that this lessened intensity of pressure is responsible for the almost complete absence of tread and ply separation. By dwelling on Figs. 5 to 9, showing the tires rolling over obstructions in the road, one can more or less sense that the tire, instead of resisting the blow that the road gives, yields with no destructive effect. For instance, one interesting point is the fact that air-cushion tires run their life with no tread-cuts whatever. I have seen many tires that have covered more than 7500 miles which were so free from tread-cuts that, had they been washed-up, they could be taken for new. The same thing applies to the side-wall of the tire; that is, in running in ruts or against curbs or loose rocks in the road, an ordinary pneumatic tire is apt to have the side-wall scraped or abraded. With air-cushion tires, however, the tire yields to the blow, thereby protecting itself and escaping injury.

Misalignment of the front wheels manifests itself very quickly by rapid tread-wear. In the few cases that we have observed, however, we have had no trouble in eliminating this by prompt attention to the realignment.

With long tire life, protection of the car against destructive vibration effects and favorable fuel-consumption, I believe the cost of car operation will be lower.

FIG. 12—ONE OF THE FOUR-PLY 7.30 TEST-TIRES THAT FAILED AFTER HAVING WORN THROUGH THE BREAKER AND THREE OF THE PLIES

At present, it is not possible to give any comparative tire costs because we have not had an opportunity to get volume production figures. The manufacturing details will



	Principal Dimensions							
Nominal Size	Actual Tire Section A	Overall Diameter B	Rim Width C	Rim Diameter D	Flange Height E	Overall Width of Rim F	Ratio of C/A, per cent	Rim Size Old Design
4.40	4.40	29½	3.06	20	0.58	3.06	45+	26×3
5.05	5.05	31¼	2.31	20	0.68	3.43	44+	27×3½
6.20	6.20	35¼	2.68	20	0.78	3.89	43+	28×4
7.30	7.30	35¼	3.12	20	0.87	4.38	43-	29×4½

FIG. 13—TENTATIVE PROPOSAL OF AIR-CUSHION TIRE AND RIM SIZES FOR PASSENGER CARS

be sufficiently different from those of regular pneumatic tires to have a slight influence tending to increase the tire cost.

Other factors that have a larger influence on the cost element than the manufacturing processes are the section size of the tire and the number of plies to be used. Comments are made and comparisons are drawn on section measurements and the number of plies, later in the paper. In a general way, as a result of our development work, I have concluded that the amount of cotton and rubber used in air-cushion tires need not be much greater, if any, than that in the tires which they replace. Therefore, if we increase the section, we can make a corresponding decrease in the thickness of the walls of the tire. However, until the actual sectional sizes to be put on the market are decided upon, it is not expedient to attempt to forecast precise cost figures.

LOW-PRESSURE TIRES APPLIED TO AUTOMOBILES

The foregoing covers our research development-work on the fundamental air-cushion idea. The result of all these activities since early in the fall of 1922 has been to confirm our judgment that we are working on a sound basis. The next logical move is to translate the low-pressure principles into practical application to motor cars, with the aid of the motor-car engineers.

To provoke discussion and drawn forth constructive criticism, I know of no better way than to propose what appears to me to be an ideal line-up of tires and rims. This was suggested earlier in the paper and is now presented more in detail in Fig. 13, which shows an outline drawing of a tire and a rim and gives the principal dimensions. The 4.40-in. air cushion tires of either two

or four plies on a 3-in. straight-side rim is proposed for cars having approximately a 100-in. wheelbase that now use 32-in. pneumatic tires. The 4.25-in. size using four plies on a 3½-in. rim is intended as a substitute for 4-in. regular pneumatic tires on cars that have wheelbases ranging from 109 to 113 in. The 6.20-in. size using either four or six plies on a 4-in. rim is designed to serve in place of some of the 4½-in. and most of the 4½-in. regular pneumatic tires on cars that have wheelbases ranging from 115 to 120 in. The 7.30-in. air-cushion tire using four or six plies on a 4½-in rim is offered to serve in place of a four 4½-in. and all 5-in. regular pneumatic tires to applied to cars having a 130-in., or longer, wheelbase. Each one of these four sizes has been fitted to a job in the group for which they are recommended, and it is our thought to receive comments on how successful we have been in working up this specific proposal.

In submitting this proposal, which is based on our experience in road tests combined with experimental application to motor cars, we believe that, when finally worked out to the state where it is suitable for commercial use, air-pressure recommendations ranging from 20 to 35 lb. per sq. in. will be satisfactory. Also, our tests have shown that the 45-per cent ratio of rim width to tire section as a basis of tire design, while being somewhat of a radical departure from the 10 to 12-year-old criterion of 66 per cent, is practicable so far as tire performance is concerned, has the exceptionally meritorious advantage of making a substantial reduction in the unsprung weight and, finally, is the most efficient combination of the number of plies and tire section to result in tire costs that will not be burdensome to the industry.

It seems to me that the car designers must view this problem from two aspects: first, whether there is anything inherent in the application of such tires to the car that makes them undesirable; second, the specific changes in the body, the axles, the fenders and the other features of car design that the designer would need to undertake to accommodate some changes in physical measurements.

Dwelling for the moment on the fundamentals underlying this movement, I ask: Does the motor-car industry wish to go as far as this proposal? Does the industry wish to have narrower rims and a light carcass-structure in the tire, or would it rather go to some half-way point? For instance, whereas I propose a 7.30-in. four or six-ply tire on a 4½-in. rim for cars having a 130-in wheelbase, would it be along a line of less resistance and more appeal to the car builders to use a smaller section, say a 6-in. six-ply tire on a 5-in. rim, or would the 7.30-in. section tire be suitable if it were on a wider rim; and so on down the list of sizes? Bearing in mind always that this ideal line-up employs the rim of lightest weight, the lowest air-pressure and the least costly tire construction, how should we modify the proposal?

To take advantage of low-pressure air, a large area of contact is necessary and a large area of contact cannot be had without a high percentage of deflection; this in turn, calls for a thin carcass and a large section. What are the problems of practical application that the car

TABLE I—WEIGHTS AND STANDING DIAMETERS OF TIRES

Air-Cushion Tires							Pneumatic Tires					
Size, In.	Number of Plies	Weights, Lb.				Standing Diameter, In.	Size, In.	Weights, Lb.				Standing Diameter, In. High and Low Values of Tires on the Market
		Tire	Tube	Demountable Rim	Total			Tire	Tube	Demountable Rim	Total	
4.40	4	15.5	2.7	11.4	27.4	29½	30x3½[a]	11.9	1.8	12.0[b]	25.7	30⅞ to 31⅝
5.40	4	14.5	2.7	11.4	28.6		Oversize Clincher Cord	14.0	2.1	12.0[b]	28.1	
							Straight-Sided Cord	14.1	2.1	15.5	31.7	
5.50	4	21.1	4.0	12.8	37.9	31¾	31x4	21.3	2.7	16.8	40.8	32⅛ to 33
							32x4	21.7	2.8	17.4	41.9	32½ to 34
							33x4	22.7	2.9	18.0	43.7	34⅝[c]
6.00	4	27.2	4.0	14.8	46.8	33¾	29x4½	22.8	3.1	18.8	44.7	30½[c]
							32x4½	25.6	3.4	21.6	50.6	33⅛ to 34¼
6.40	4	31.7	4.0	14.8	51.1		33x4½	25.9	3.5	22.5	46.8	34¼ to 35
							34x4½	27.4	3.6	23.5	54.5	35⅛ to 36⅛
7.30	4	34.8	5.4	16.0	56.3	35½	30x5	29.3	4.0	18.8	52.1	32[c]
7.30	6	39.4	5.7	18.8	63.9		33x5	37.2	4.6	21.6	63.4	34⅝ to 36
							35x5	39.4	4.9	23.5	67.8	36½ to 37½

[a] Diameter measured over rim.
[b] Estimated.
[c] Approximate.

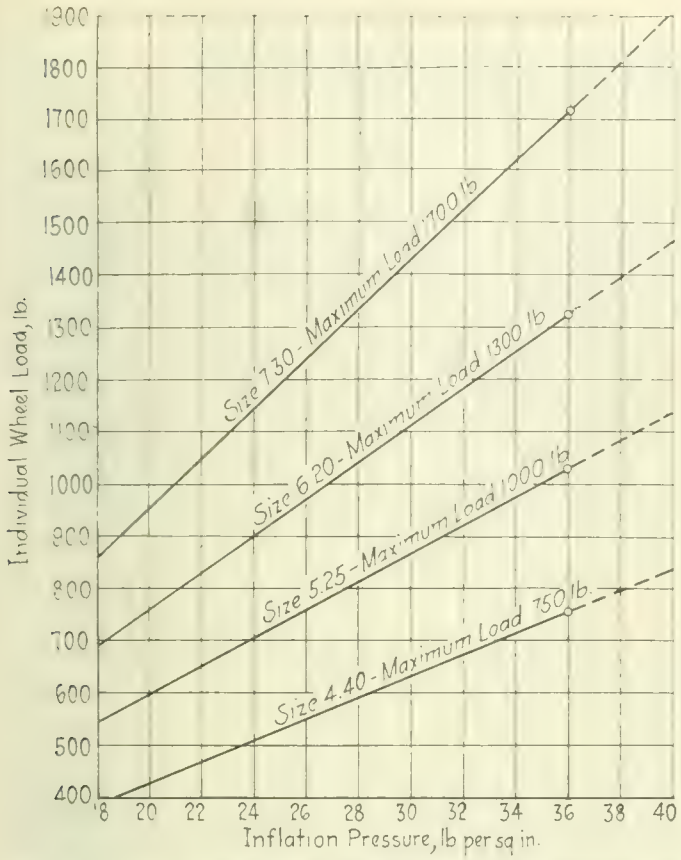

Individual Wheel Load, lb.
Inflation Pressure, lb per sq in.
Size 7.30 - Maximum Load 1700 lb
Size 6.20 - Maximum Load 1300 lb
Size 5.25 - Maximum Load 1000 lb
Size 4.40 - Maximum Load 750 lb

FIG. 14—CURVES SHOWING THE INFLATION-PRESSURE REQUIRED TO SUPPORT A GIVEN WHEEL-LOAD

designer must recognize and master? Are they fundamental and far-reaching, or are they merely clearance and gear-ratio alterations?

Changes in fender, body and brake-drum clearances and also changes in the width of tread of the car, in fitting air-cushion tires, bring up a very complex situation. But it must be accepted as a foregone conclusion that any change in tire equipment that results in the use of larger sections and smaller rim-diameters is very likely to bring about interferences and changed relations of the parts, which must be provided for. It is hoped that the automobile industry will not requisition more than one standing diameter for each section. The tire manufacturers have always been dreaming of the time when they would not need to make a series of standing diameters for each section and, whatever the final disposition of this matter may be, I bespeak for the tire industry a serious attempt to carry out some such program.

Table 4 gives weights of tires, tubes and two-piece rims such as are used for disc or wire wheels, and with the standing diameters of the tires to furnish a direct comparison of the air-cushion with the pneumatic tires.

TIRE-SIZE NOMENCLATURE

Reverting to the schedule as proposed, it will be noted that a new size-nomenclature is included. It has always seemed to me that the sizes of the tires are so far-fetched that I could not resist the temptation to propose a new disposition of this matter. I think everybody is aware that a 34 x 7-in. tire, for instance, has no part of the tire that measures 34 in. and, likewise, no part of the tire that measures 7 in. I propose that, when we finally work into air-cushion tires, the true section-size be used as the name size. It does not strike me as necessary to give a standing diameter, since there will be only one standing diameter for each section.

It is my belief that, in introducing the air-cushion tire, the industry should start with the firm determination to make oversizing unnecessary and even that it should not provide for it. Years ago, two factors made oversizing a very desirable thing. I refer to our positive lack of knowledge of how to make good tires in the early days, and to the fact that car builders did not appreciate the desirability of ample sections. That day has long since passed and, at present, the instances in which the owner needs to put on an oversize tire are extremely rare. I wish we might say the same thing about pneumatic equipment for motor trucks!

LIMITATION OF TIRE DEFLECTION

Earlier in the paper, I pointed out that the limitation of the load and inflation combination of any pneumatic

TABLE 5—RECOMMENDATIONS FOR AIR-CUSHION TIRE-EQUIPMENT AND AIR PRESSURES

Data obtained from the Tire & Rim Association May, 1923						Recommendations for Ford Car		
				Weight Ready for Road with Full Passenger Load, Lb.		Air-Cushion-Tire Recommendations		
Model No.	Wheel Base, In.	Number of Passengers	Type of Body	Front	Rear	Size, In.	Air Pressure, Lb per Sq. In. Front	Rear
			Touring	1,000	1,500	4.40	23	35
			Roadster	975	925	4.40	23	23
			Sedan	1,020	1,675	4.40	24	38
		.....	Coupe	1,085	1,200	4.40	24	28
Data obtained from the Buick Motor Car Co., May, 1923						Recommendations for Buick-Four Car		
23-34		2	Roadster	1,395	1,390	5.25	24	18
23-35		5	Touring	1,375	1,950	5.25	24	34
23-36		3	Coupe	1,500	1,550	5.25	26	26
23-37		5	Sedan	1,500	2,200	5.25	26	38
23-38		5	Touring	1,500	2,100	5.25	26	37
Data obtained from a questionnaire filled out by the Jordan Motor Car Co., Inc., May, 1923						Recommendations for Jordan Car		
M X	120	5	Touring	1,630	2,335	6.20	21	32
M X	120	5	Brougham, Four-Door	1,700	2,560	6.20	23	35
M X	120	2	Road	1,600	1,760	6.20	21	24
H	124½	4	Sport	1,700	2,275	6.20	23	31
H	124½	5	Sedan	1,860	2,645	6.20	25	35
Data obtained from the Lincoln Motor Co., May, 1923						Recommendations for Lincoln Car		
117	136	7	Sedan	2,360	3,610	7.30	25	38
118	136	7	Limousine	2,340	3,610	7.30	25	38
120	136	7	Town Car, Open Drive Limousine	2,260	3,470	7.30	23	36
123	136	4	Phaeton	2,170	2,930	7.30	22	32
124	136	7	Touring	2,340	3,250	7.30	25	34
125	136	4	Sedan	2,250	3,130	7.30	23	33
126	136	4	Coupe	2,600	2,940	7.30	27	31
129	136	5	Sedan	2,270	3,210	7.30	24	34
130	136	2	Roadster	2,120	2,275	7.30	23	24

tire is the percentage of deflection and I gave a schedule of the tires commercially in use today. I propose that the deflection of the air-cushion tires to be used is approximately 25 per cent of their section diameter. Having decided on this, it is a very simple matter to decide on the load and the inflation-pressure schedule by weighing the loads that the 25-per-cent deflection will carry per each pound of inflation. This is set forth in graphic form in Fig. 14. I propose this as a load and inflation-pressure schedule. In applying it in practice, I believe it would be well to publish the graph along with the price-lists and try to translate it into a table of load and inflation pressures as has been done in the past. It seems to me that the only logical thing to do is for each car builder to weigh the front and the rear of each of his models with full-passenger load. With the tire equipment decided, check off the proper inflation for each end of the car, stamp it on a steel plate and attach it to the car in some conspicuous place so that the car-owner can feel that this subject has been given consideration by the car builder and that he has the builder's best judgment as a guide to what he should do. It is my judgment that air-cushion tires should be inflated very carefully and should check to within 1 lb. of the correct pressure. A typical example, one for each size of tire, and the disposition of the air-pressure problem, appear in the Appendix.

APPENDIX

As a basis for stating recommendations, a Ford car on 4.40-in., a Buick-Four on 5.25-in., a Jordan on 6.20-in. and a Lincoln on 7.30-in. air-cushion tires were picked out as typical examples to show our method of distinguishing between the different models and also between the front and rear of each model in regard to the amount of air pressure. The range of pressures used on any one make of car must necessarily be given greater attention than heretofore if we are to enjoy the best effect in the use of air-cushion tires. Of course, all makes of car have been treated similarly and the detailed information is available for each maker. The recommendations for the foregoing makes of car are stated in Table 5.

AIRCRAFT-ENGINE PRACTICE APPLIED TO PASSENGER CARS

(Concluded from p. 22)

dirt on the cylinder walls and the fins may not have much effect on the cooling of a small low-duty lighting-engine, this is no proof that it is not desirable to design so that dirt deposition will be a minimum and that any such accumulation shall be readily apparent, accessible and easily removed. One highly successful manufacturer of air-cooled aircraft-engines recommends that the dirt accumulation on the cylinders should be removed after every flight; but, while such precautions are entirely unnecessary on a car engine, the effect of scale deposits in water-cooled engines should be sufficient to show that heat-insulating deposits are undesirable on the surfaces to be cooled. I think that Mr. Dicksee is on rather unsafe ground when he attempts to draw so many conclusions on air-cooled engines generally from experience obtained with a small low-duty engine.

The characteristics of the air flow in the cells of the axial and circumferential-fin types are of radically different nature. In the axial-fin type the slowly moving air is accelerated suddenly on entering the cell and, in addition, has added eddy losses due to the square edges usually found on the fins in this type. In the circumferential-fin type, the air enters the cell at a low velocity over rounded fin ends and is accelerated gradually toward the throat, the plan shape of the throat somewhat resembling a venturi, as shown in Fig. 15 of the paper. This condition will exist in either a multi-cylinder engine or a cowled single-cylinder engine.

Cylinder-barrel temperatures do not in general exceed 350 deg. fahr. in aircraft engines, but it would be rather daring to suggest that this is the maximum allowable. I have run a 5-in.-bore aircraft-engine cylinder run wide-open for three hours with all the fins removed from the barrel, without any trouble occurring. After this test the piston skirt was almost completely covered with black tarry oil, but was otherwise in good condition. The plain cast iron of course, with a close-fitting aluminum aircraft-type piston and ample lubrication; with car-engine conditions the result might be very different.

The problem of cylinder-temperature control in air-cooled engines mentioned by Dr. Dickinson is a matter of no great difficulty. Control of the cooling-air supply by manually operated shutters or otherwise thermostatically controlled by the cylinder-head temperature or by the temperature of the cooling-air after it has passed over the engine, provide a ready means of control of the engine temperature. In any case, the air-cooled engine has a considerable advantage over the water-cooled type, owing to the much smaller heat-content of the engine at its normal working temperature; thus, the air-cooled type will reach its working temperature in a much shorter period. One builder of air-cooled cars has found that the rapid warming-up materially reduces the carbon deposit.

The effect of the cylinder-wall temperature upon the fuel economy is not thoroughly known, and some recent work by the Engineering Division is of interest in this connection, although conducted with wide-open throttle and aircraft fuel. Since the publication of the paper, further work has been done on the cast-iron Type-K cylinder. All the cooling fins were removed and a steel water-jacket welded on. In this form, no increase of output was obtained; the fuel consumption with which the maximum load could be held was reduced by about 4 per cent, although the minimum fuel-consumption obtainable was no lower than with the air-cooled cylinder. In spite of the fact that in the water-cooled cylinder the wall temperature at T_w, as shown in Fig. 1 of the paper, was only about 185 deg. fahr., the tendency to detonation was reduced but slightly. This is remarkable when it is considered that the air-cooled cylinder developed a temperature of more than 700 deg. fahr. at T_1 under similar conditions.

The foregoing results tend to confirm Mr. Grimes' observations regarding cylinder temperature and fuel economy, but it may be well to state that, in general, high wall-temperatures in air-cooled cylinders result in an excessive fuel-consumption at full throttle; so much so that, in fact, such engines, and the Renault and early R.A.E. designs come in this class, are more suitably described as fuel-cooled than air-cooled.

Science and Engineering

By J. H. Hunt[1]

Indiana Section Paper

DEFINING science as "the search for and the classification of the knowledge of natural phenomena," and giving a definition of engineering as being "the application of the materials and the forces of nature to the use of mankind," the author discourses at some length in comparing the conditions under which a scientist works with those that affect the work of the engineer. Time limitations for completed work, and the relations of theory and practice are accorded somewhat similar treatment.

Several examples are given showing how the engineer and the scientist have vied with each other in making progress, and predictions are made that other new materials will be discovered and that the scientist will communicate the scientific method of working to the engineer of the future.

THE relations between science and engineering involves such important problems affecting the future of the engineer, that it is really very presumptuous for one who knows only a little about engineering, and really nothing about science, to attempt to discuss them. However, some points can be made in the hope that better qualified persons will take up the subject.

We hear much about "pure science" as being something very distinct from, and possibly elevated above, commercial affairs. If there is such a thing as "pure" science, it is science pursued for its own sake, without regard to the value or the cost of the information obtained. The attitude of the pure scientist is explained, in a way, by a story told of a certain meeting of a mathematical society. A very learned specialist in a very little known form of mathematics read a paper covering the results of several years' work and concluded with the pious hope that his work was so intricate, and so far removed from the ordinary types of mathematical knowledge, that there was no danger that this new found knowledge could be polluted by being used by anyone but a mathematician. The discussion was opened by a physicist who stated that he had been looking for a mathematical tool capable of solving a problem that had baffled him for 2 years; and the mathematician had just supplied him with this tool. I have no doubt that, sooner or later, if it has not happened already, some inventor or some engineer will use this same principle in some device in the practical affairs of mankind.

Illustrative of this same viewpoint, a story is told of Joseph Henry, who was one of the fathers of American investigation in physical phenomena. Following the work of Faraday, he studied the behavior and the laws of the electromagnet, and published a theory explaining how electromagnets might be designed. It is said that he was highly indignant at a friend who suggested that Henry had really invented the telegraph, and that he should have patented it, instead of leaving it to Morse. While the story may not be true, the fact that it has been repeated for years illustrates the point of view of the scientist of that time, and for much of the time from Henry's day until the present. Fortunately for the progress of mankind, there are few scientists today who prefer to work on problems having no prospect of application to human affairs. The time between a discovery and its practical application grows shorter with every decade.

To simplify our discussion, we will define science as "the search for and the classification of the knowledge of natural phenomena," and engineering as "the application of the materials and the forces of nature to the use of mankind." These definitions are not so good as some others, but will be sufficient for our immediate purpose. A comparison of the conditions under which a scientist works with the conditions affecting the work of the engineer will explain many of the relations between their work.

Scientific Working Conditions

When we visit the laboratories of the scientists, whether in the university, a Government department or a commercial-research organization, the first thing that impresses us is the extent to which the scientist works as an individual. He not only plans his work, but sets up his own apparatus. Frequently, he designs the auxiliary equipment and is very likely to make a considerable portion of it with his own hands. This statement is more nearly true of the university worker than of the laboratory man in a large industry, but it is true to a much larger extent for the latter than for the engineer. Not only is the work done on an individualistic basis, but the reports are made on the same basis. The scientist is very careful to give credit to predecessors and colleagues, and expects to and does receive personal credit for his own contribution. This results in his coming into competition to a certain degree with the workers in his specialty over the whole world. This tends not only to give him a greater respect for himself and his work but also to make him very careful in his claims for his work, for he knows that it will be subjected to a careful analysis by men every bit as good as he is, with the possibility that much better minds will review it, locate any possible fault and overthrow any unfounded claim.

The important thing to the scientist is accuracy. Cost, in time or money, enters in no way into his calculations, provided he can obtain the necessary minimum of money for the needed equipment. Since no commercial value is placed on the result, he does not need to concern himself about the ratio between the cost and the value of the product. This attitude is of course perfectly justified, since no one can place a value on a new scientific fact. It is only a little over 90 years since Faraday demonstrated the laws of electromagnetic induction. Without a knowledge of these, practically all of our electrical applications in the arts today would be out of the question. It is said that at the end of his very simple, original demonstration, a lady in the audience asked "Of what use are these new phenomena?" and that Faraday answered, "Of what use is a new-born child?" The question and the answer typify clearly the usual attitude of the public and of the scientist.

The scientist not only publishes the results of his work as an individual, but he is under considerable pressure

[1] M.S.A.E.—Head of electrical division General Motors Research Corporation, Dayton, Ohio.

that his work will be judged by other engineers of equal ability until his firm is definitely committed to a product that may lead to bankruptcy.

As a general proposition the engineer cannot publish very much about his work when it is new. His intended publications are likely to be subjected to censorship from such widely diverse viewpoints as those of the patent and the sales departments of his company. When these two groups are through, there is usually not enough left of his proposed paper to justify publication anywhere. Many have doubtless noticed that, in many lines in the pre-war days, the foreign technical press seemed to be more worthwhile reading than the American in the same line. While Europe was often in advance of us, the difference on the average was not so great as the technical magazine would often indicate. The foreign engineer was in a position to give his results to the world sooner than the American, for two general reasons. The first of these is the result of the difference in the patent laws. In America, it is often years after the patent application is filed before it is definitely settled whether there was an invention, and who made this invention. It is hardly necessary to remind automobile men of the Selden patent. Until such questions are finally settled, anything that any engineer says about the subject is liable to be used or misused in a patent controversy. Foreign patents, as a general proposition, go to the party first applying rather than to one who claims to be the inventor, and action is usually more prompt than in the United States. As a result, the patent situation clears up much earlier. Relatively more business is done by small companies in Europe than in America, these companies calling in outside consultants for all except routine engineering work. These gentlemen frequently have contracts giving them certain rights in the results of their work. The papers they publish become high-class advertising, not only of the particular result but of the engineer's ability to accomplish these results. The technical press naturally benefits.

The engineer must above all things count costs, not only the cost of producing the final result but also the cost of obtaining the data that will enable this product to be designed. If he fails in either, he will cause his company great difficulty. Some years ago the following advertisement appeared in an electrical magazine: "Wanted—An engineer to design a line of small direct-current motors, no experimenter need apply." This particular company would never get a satisfactory engineer on that basis, but it is pretty safe to say that it was in the pain of parting with an engineer who had failed to estimate correctly the cost of his development work. The engineer must have a pretty definite idea as to the value of a piece of information he expects to get by experimentation; otherwise, he can easily spend more than it is worth in trying to get it. Because of a frequent failure to analyze properly, he often fails to have much of a picture as to what it is likely to cost to get the information, and this is one of the lines in which the engineer needs to improve his work.

Time Factors

The engineer is always working against a due date. Sometimes it is a bogey he sets in his own mind and sometimes it is set by the management, but always there is a possibility that some competitor will reach the result he has in mind first. He is, therefore, under a great temptation to start work before he has studied the problem properly. Usually he does not give enough attention to what has gone before, and this attitude is

unfortunately partially justified by the fact that so many engineering data that have been published are almost worthless except to the man who obtained them, because the conditions surrounding the work were not set out in sufficient detail and it is not safe to make very many deductions. Also, most successful engineering is done along lines where others have made only partial success or even failures. This fact, however, does not justify the complete rejection of all that can be learned of a predecessor's work, and engineers frequently are guilty of just this fault.

The engineer is under more pressure than the scientist to cover rather completely the field of his own work. Too much is dependent upon his making sure that some unforeseen and, apparently, small factor will not interfere with the success of his apparatus. Since it is humanly impossible to predict all of the details that may arise, the engineer is compelled to make more or less blind thrusts in various directions to determine what may possibly happen. An automobile engineer calls these thrusts road tests, and they take the form of sending a completed assembly of more or less completely tried details to the Pacific coast or to Florida and back, depending upon the inclination of the engineer. Sometimes he learns something he could not have learned in the laboratory or by a dynamometer test, but more usually every point he thinks has been settled by such a test could have been settled with much less expense within 10 miles of the factory. Possibly, part of the fault is with the management. If the engineer could get a reasonable vacation by other means, he might be able to see how to get along without road tests crossing so many state lines.

Theory and Practice

A common criticism of the scientist is that he is too theoretical. The criticism is doubtless justified. But many engineers are more theoretical and it is usually the one who insists most on his practical viewpoint who is the most theoretical. A theory is simply an explanation for a fact or a group of facts. As a general proposition, the more facts a theory explains, the better it is as a theory. About 2000 years ago, the average man had a theory that the earth was flat. This explained the fact that it looked flat, and explained very little else. More than 2000 years ago, a Greek philosopher at Alexandria had a theory that the earth was round. This theory explained several facts to which the ordinary man gave but little consideration, such as the rising of an object above the horizon as one approaches it, and the rising and the setting of the sun. By having measured the lengths of shadows at noon on the same day at two points on a north-and-south line, he computed the polar circumference of the earth to a very high degree of accuracy. It does not seem reasonable to say that the philosopher was more theoretical than the common man so far as their ideas regarding the scope and the size of the earth were concerned.

Not all the engineers are yet dead who once had a theory that a hotter spark increased the power of an engine. This theory explained the fact that a weak battery with the old-style vibrator-coil sometimes led to a condition where an engine overheated and lost power. Everyone of these engineers who used this theory to explain a fact that they had seen, or heard of, on good authority, would have denied indignantly that it was in any way a theory, or that they reasoned theoretically. A theory that simply explains some known facts may be interesting, but it is of very little value unless it enables one to project forward and say that, if this theory is true, then some as yet unknown fact must be real. This suggests at once that a test can be made to determine the existence of the supposed fact. The test is then made, and something more is learned at once. The results of the test may confirm the theory, which is then stronger than ever, and we have as a by-product of the study a new proved fact. The results may be opposed to the theory and we are on the way to a correct theory.

A beautiful example of this type of thing has led up to the recent theory of Einstein regarding relativity. From the days of Newton until early in the last century, scientists discussed the nature of light. Finally, the wave theory seemed to win and, as a result of this and of Faraday's work on electricity and heat, Maxwell developed his theory of the luminiferous ether, through which light waves could travel. This suggested that, if delicate enough measurements could be made, enough difference in the speed of light could be detected under certain conditions of measurement to determine how fast the earth is traveling with respect to the ether. Michelson and Morley, and later Morley and Miller, made the attempt and failed to find the difference in the velocity. Einstein took this fact and simply postulated that light always travels in a given medium at the same velocity and, by mathematical deduction, worked out his theory of relativity. As a result of his mathematics he announced his theory according to which three things would follow: First, the major axis of the orbit of the planet Mercury would revolve at a certain very slow rate. It is known that it does revolve at a rate very close to the requirements of Einstein's theory. Second, a ray of light will bend in a gravitational field; that is, when it passes close to a large body like the sun. Third, the rays of light originating on a large body like the sun will have a very slightly longer wave-length than the light rays given off by the same substances on the earth. To settle the second prediction, photographs of stars apparently close to the sun are taken during solar eclipses. Three years ago, two expeditions succeeded in getting one photograph that seemed to confirm Einstein's theory. More photographs were attempted last summer, but all of the reports are not in.

Astrophysicists are not only taking new spectrograms of the sun, but are studying old ones in an effort to settle the third prediction. This effect is so small that other effects such as solar cyclones and varying pressures may easily cause greater effects, and many American students are skeptical that Einstein's third prediction is correct although some Germans say it is.

In the long swing of the progress of knowledge it makes no difference whether Einstein is right or wrong. He has stimulated the scientists of his time tremendously, and we shall not only learn much about conditions on the sun and about astronomy but also considerable about the chemistry of the photographic plates and their behavior during development, before the effect of this stimulus wears out.

When the scientist discusses our civilization of today, he is inclined to claim most of the credit for the rapid advance in material comfort and control over nature that has come in the last 150 years. Engineers make the same claims for their profession, pointing out that our civilization is based on modern methods of production, transportation and communication that are under immediate control of the engineer. As a matter of fact, the result we have is due to the combined efforts of both, the scientist being sometimes ahead of the engineer and sometimes the engineer has preceded the scientist who

to the third electrode when the filament was hot, the electrode being negative. This occurred without any apparent connection between the filament and the electrode inside the lamp. He followed this idea far enough so that he took out a patent before 1890 covering a wireless system involving this principle. The patent specification indicates that he had sent signals in a laboratory. It also shows that the idea of tuning was not known. This required some preliminary work by scientists, although as a matter of fact, the basis was all laid at this time. Years later Dr. Fleming, a scientist, who assisted Marconi, took advantage of the Edison effect, as it was called, and produced the Fleming valve for use as a detecting device. DeForest improved the idea by the addition of a third electrode in the bulb, producing the audion that is a still better detector. A large number of experimenters took the three-electrode tube and brought the wireless art to the position it occupies today. This whole wonderful device is founded on the work of scientists, and its development is principally due to scientists, yet we have two discoveries of vital importance coming first from engineers.

Predictions

Prophecy is an exceedingly dangerous thing. Rowland was probably the foremost American physicist of the past generation. When at the height of his reputation, he made the prediction that the work of the physicist of the future was to consist of rechecking the work of his predecessors and improving their accuracy and determining the constants such as the velocity of light to more significant figures. In his opinion, the fundamental discoveries were all made. Immediately after this the negative particle of electricity that we call the electron was discovered, leading directly to the discovery of X-rays, and to facts regarding the constitution of matter of such vital importance that the physicist and the chemist of today have an entirely different picture of the nature of the universe from that held by Rowland. If the best physicist of his time could be so far wrong, the danger to an engineer of prophecy is obvious, but two predictions will be risked.

One of the most important contributions of the scientist in the past has been new materials, or old materials improved so that they are entirely new for engineering purposes. The present generation of automobile engineers has seen aluminum develop from an expensive material that hardly could be called a metal, so far as its physical properties are concerned, except for the fact that it could be cast, into a material that can be produced as strong as mild steel and that can compete with steel on a cost per result basis. Pure tungsten was practically unknown 20 years ago and, when first produced, it scarcely could be put into a form where it could support its own weight. Today, the tungsten wire in lamps having the finest filaments has a tensile-strength of over 500,000 lb. per sq. in. This again is the result of the work of the scientist. With such examples of past contributions of materials, we confidently can expect more in the future.

Another contribution of great importance that the scientist will make to the engineer in the future is the scientist's method of working. The only reason the scientist has not made this contribution already is because the average engineer has not been ready to receive it. The scientist analyzes his problems, divides the

(Concluded on p. 62)

Four-Wheel Braking Systems

AN important feature of the Semi-Annual Meeting of the Society held at Spring Lake, N. J., June 19 to 23, 1923, was the presentation of three papers dealing with the general subject of four-wheel braking-systems for automotive usage and the interesting discussion that followed. Three types of brake were described and commented upon by the authors of the three papers printed herewith, including one of the hydraulic type and two types of mechanical systems, the intention being the presentation of an unprejudiced symposium on the merits and demerits of four-wheel braking in its application to the motor vehicle. Two of the papers are printed below.

MECHANICAL BRAKING ON FOUR WHEELS AS A PRESENT AUTOMOTIVE NECESSITY

BY ALVIN M. YOCOM[1]

THE author states that, when used in conjunction with the braking effect of the engine, two-wheel brakes work well in retarding a car on long or heavy grades, but that, for emergency stops, which are by far the most frequent, two-wheel brakes do not give a driver the positive control of the vehicle and the sense of security that are imparted by the retarding effect of braking on four wheels. The mechanical four-wheel braking-system manufactured by the company the author represents is described and illustrated, the claim being made that the front-wheel portion of the system can be connected and equalized with any of the present-day rear-axle or transmission brakes without discarding any of the rear-axle or transmission brake-material. The equalization of brakes is discussed in some detail, inclusive of foreign practice, and other features such as "fight" in the brake-pedal, the mounting of the steering-arms and the distribution of shoe pressure to prevent chattering and "grabbing" are considered.

WITH regard to the possibility of reducing car weight and complication by removing the brake rigging from one truck on each railroad car, a railroad maintenance official would say immediately that it would be impossible to do so and maintain present railroad schedules safely. Further, he would state that the wear due to braking on one-half of the normal braking surface would cause such a rapid deterioration of brake mechanisms that using this type of construction would not be a sound policy economically. Per pound of load, railroad equipment is much heavier than that used for motor transportation, but most of the braking in railroad service is done at predetermined points; motor vehicles are manipulated under exactly the opposite condition. To miscalculate by a fraction of a second often means a crash; grades are steeper, acceleration is faster and frequently two cars are each driven directly into the path of the other.

Used in conjunction with the engine, two-wheel brakes work very well in retarding a car on long or heavy grades but, for emergency stops, which are by far the most frequent, this method is impractical and two-wheel brakes do not give the driver the positive control and the feeling of confidence and the sense of security that are imparted by the retarding effect of braking on four wheels. The company I represent has evolved the design shown in Fig. 1 after a number of years of study, experiment and production of four-wheel brakes.

Two shoes inside of the drums are expanded by toggles

[1] M.S.A.E.—Chief Engineer, U. S. Axle Co., Pottstown, Pa.

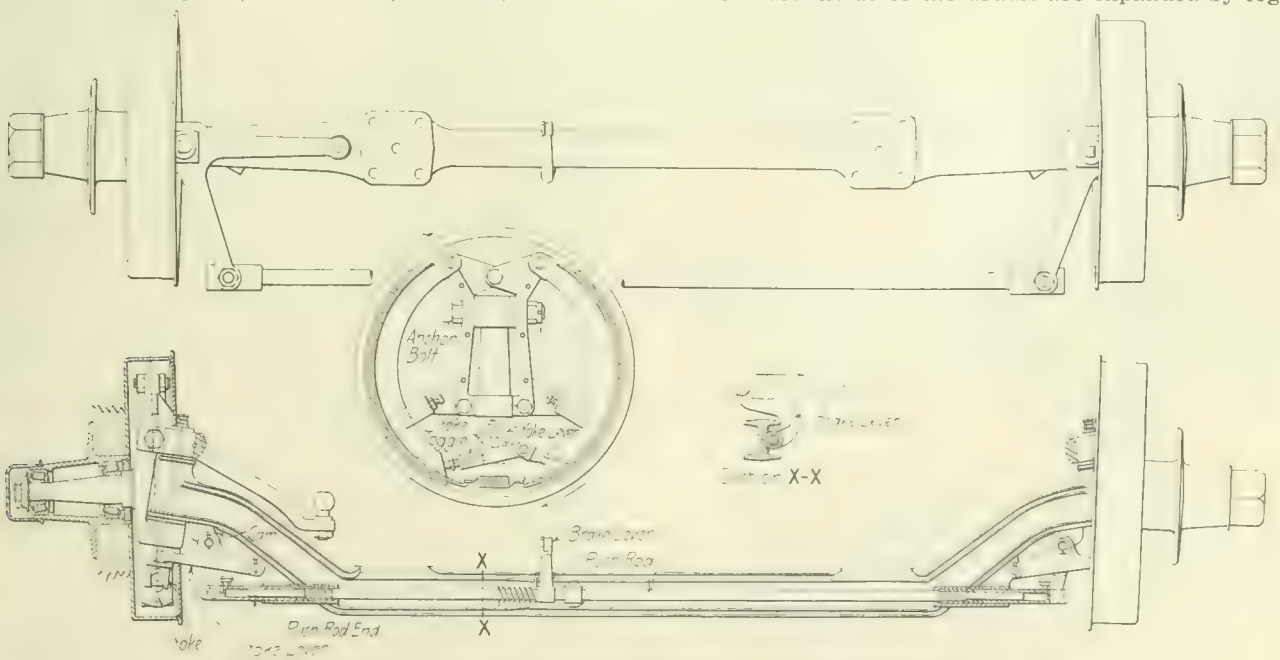


FIG. 1—DETAILS OF A RECENTLY EVOLVED TYPE OF FRONT-WHEEL BRAKE

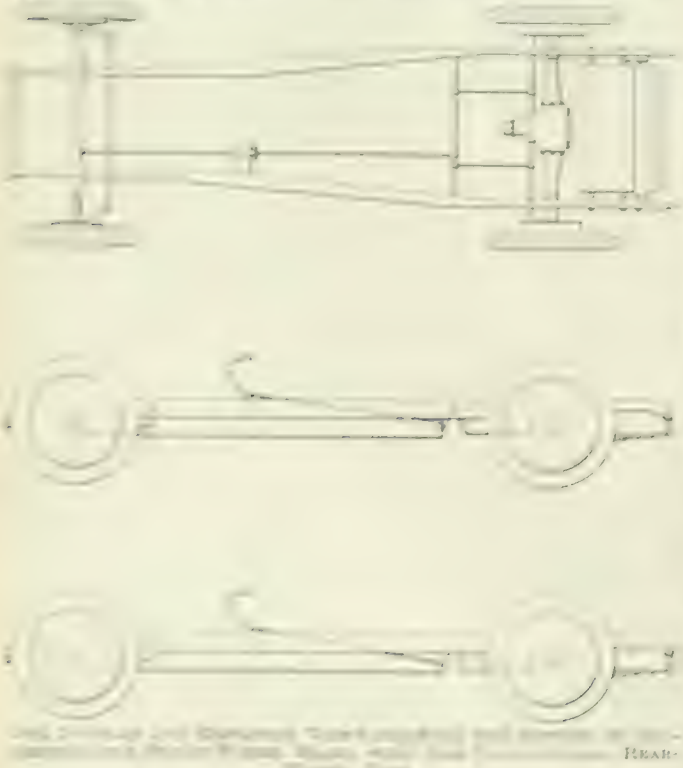
and the toggles in turn are expanded by the moving down of the yoke. The yoke is moved by the fingers, which are actuated by a cam that bears against the beam. The cam ends are moved outwardly by threaded sleeves, which are actuated by rotating a rod. The rod is rotated by a bevel-gear connected with the brake pedal. The front-axle brakes are equalized by the rod in this manner, and the threaded sleeves that between the cam ends. The connection between the cams and the sleeves is such that any beam deflection causes a sliding action between the threaded sleeves and cam ends and destroys any tendency to bind.

The type of front-wheel brake can be connected and operated with any of the present-day rear-axle or transmission brakes without discarding any of the rear-axle or transmission brake-material. Fig. 2 shows the mode of connection with the rear-axle brakes. Fig. 3 shows a typical layout, illustrating the connection between the transmission brake and the front-wheel brakes.

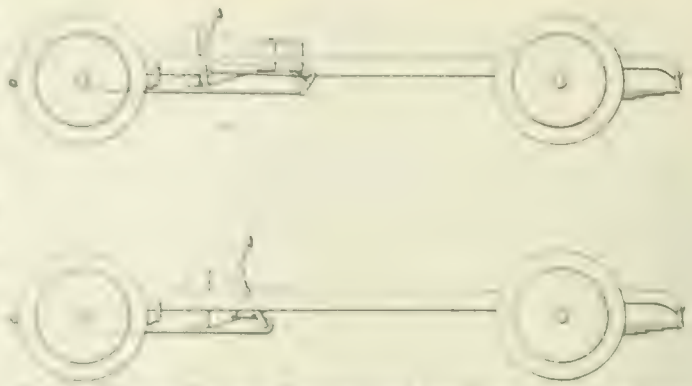
Equalization

In further reference to Fig. 1, if a cam be used to expand the brake-shoes, the latter must be machined accurately and the brake-lining mounted without a pucker between the rivets. If this work is not done accurately, one shoe will make contact with the drum and the other shoe will not; the result is low braking efficiency. This toggle type of expander is self-centering; if one shoe makes contact before the other, the reaction of the contact of one shoe forces the other shoe into place; thus, compensation is made for any machining or lining inaccuracies that may occur.

This equalizing is carried out fully also in equalizing the front-wheel brake with the other. If one pair of shoes makes contact before the other, the threaded sleeves and the rod immediately slide toward the non-contacting shoes and force them into position. With certain modifications, the sliding-rod construction can be used also for equalizing the rear-axle brakes. If this type of design is used in both front and rear axles, one



Rear-



Typical Layout Illustrating the Connection between the Transmission and the Front-Wheel Brakes

actuating rod from the front axle and one actuating rod from the rear axle to the brake-pedal are all that are necessary to apply the brakes in four drums; less length of actuating rod is used to apply four brakes in this manner than is now used to apply two-wheel brakes.

Foreign Equalization Practice

Many foreign designers use two lines of rods and several equalizers. Close study of their layouts discloses the fact that, due to frame distortion, spring deflection and the use of cam action, it is possible to have one shoe making contact in one front drum, one shoe making contact in one rear drum, and the other six shoes not even touching the drums; of course, as the wear in the two shoes progresses, the other six shoes finally take their place. Let us assume now that all shoes make contact, but that loading, heat and moisture cause an uneven swelling of the lining or a distortion of the shoes, the drums, the frame and the springs. These factors cause further trouble, and the brakes do not hold properly; again, all the shoes are not making contact and they must wear-in to compensate for these added conditions. Therefore, braking conditions vary continually.

Types of Construction

The use of a full-reacting type of construction is the best assurance that eight shoes or four bands will make contact with the drums from the time the brake-linings are renewed until they are worn thin. It is the one construction that wholly compensates for production and other deforming inaccuracies and gives a reasonable brake equalization regardless of the manner of brake adjustment. A full-reacting type of brake is one in which the reaction of the contact of one shoe must force the opposite shoe into contact, and the reaction of one pair of shoes must force the other pair of shoes into contact. The reaction on the front-brake pull-lever must exert a pull on the rear-brake pull-lever, or vice versa.

In driving over a rough surface there will always be more or less "fight" in the brake-pedal; but, with this reacting type of brake, each pound of pedal pressure will be multiplied many times, eight shoes or four bands will be expanded almost simultaneously to be in contact with the drums and the retarding effect will be a delightful revelation to the driver. Over rough roads, it is impossible to force eight shoes against four drums unless full-reaction construction is used; anything short of this will result in uneven wear of the lining and faulty unequalized brakes.

Steering-Arm Mounting

Attention is called to the mounting of the steering-arms. They are yoked over and reinforce the steering-

knuckles. The connection of the steering-arms and the steering-knuckles is made inside the drum-covers. This makes the clean construction that is so desirable on the front wheels. Bolt-heads and uneven drum-covers give a clumsy appearance to front-wheel brakes. The brake-anchors are secured by the same bolt that clamps the arms, but it holds both arms and knuckles in such a manner that it is not directly stressed by either member. This construction is very simple, accessible and easily dismounted.

Reinforcement and Steering Ability

There is always a tendency to fracture the steering-knuckle just outside the steering-pivot bearing. This part is strengthened by carrying the brake-anchor down and bolting it fast to the steering-knuckle, thus giving the knuckle a much higher factor of safety. The steering-arm knuckles and brake-anchors are grouped to reinforce one another and this results in a unit that is not only light in weight but also strong in its construction.

If the front wheels are retarded to such an extent that they cease to rotate, the driver is unable to steer. To eliminate this danger, the operating yoke is arranged so that it makes contact with the toggle-bar on a skew; this causes a lighter pressure on the shoe that tends to wrap into the revolving drum than it does on the shoe that tends to be forced away from the revolving drum. This distribution of shoe pressure gives a surprisingly smooth but positive retarding effect, and the danger of chattering and grabbing of brakes is wholly avoided.

Although many of the present two-wheel and transmission brakes are very efficient, an automobile cannot be brought to a standstill with the rapidity with which an electric car or railroad train is decelerated. Numerous accidents point to the necessity of better brakes. If all that possibly can be done has been done to create the best rear-wheel brakes, the next step is the adoption of a simple dependable four-wheel-brake system.

THE RENAULT MECHANICAL FOUR-WHEEL BRAKING-SYSTEM

BY MARCEL GUILLELMON[2]

THE high car-speed demanded by present-day drivers of automobiles is stated by the author as having necessitated braking systems that more adequately overcome the effects of such increased momentum than is possible with ordinary brakes applied only to the rear wheels. Since, at the time the brakes are applied, the greatest part of the weight of the car is thrown upon the front axle and the front wheels, he believes it imperative that brakes be applied also to the front wheels and demonstrates that this also prevents skidding as well as increasing the braking effect.

The four-wheel braking-system of the Renault car is then illustrated and explained in detail, and the advantages of this servo-brake system in regard to braking power, smoothness of operation and adequate car control, are set forth.

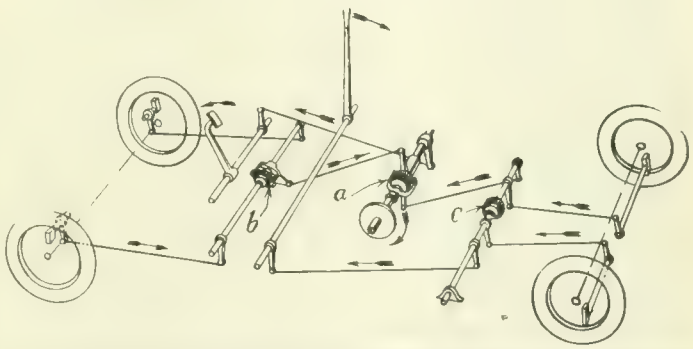


Fig. 1—Diagram Illustrating the Arrangement of the Renault Four-Wheel Brake-System

OWING to the public demand for high speed and the consequent greatly increased speed-ability of present-day motor-cars, braking systems that adequately overcome the effects of such increased momentum become an imperative necessity. At car speeds of more than 40 m.p.h., I believe it to be unsafe to attempt to stop a car quickly if it is equipped only with ordinary brakes that act solely upon the rear wheels. In fact, it is abnormal to exert the retarding effort only on the two rear wheels because, at the time the brakes are applied, the greater part of the weight of the car is thrown upon the front axle and front wheels. Besides that, when the ordinary brakes are applied too suddenly to the rear wheels, the car has a tendency to skid laterally. Therefore, brakes should be applied also to the front wheels, since brakes applied solely to the two rear wheels have proved to be insufficient.

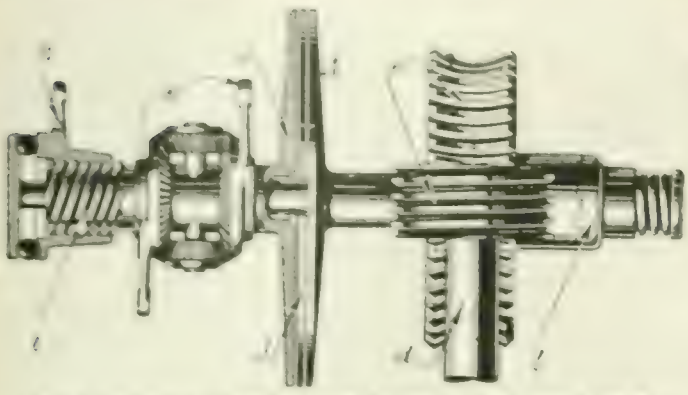
In 1921, Baudry de Saunier, the editor of *Omnia*, Paris, France, showed very positively that front-wheel brakes will prevent skidding. To demonstrate the method of proof, I will use a small toy automobile and place it at the top of an inclined surface that represents a steep grade, such as an inclined sheet of stiff cardboard. If the driving wheels of the car are in normal position and can travel in a straight line, the car will run rapidly down the inclined surface. Now let us make the same experiment and lock the rear wheels. Then we will notice that, as the car runs down the incline, the rear end skids slowly and that the car turns through a semi-circle until the rear wheels occupy the position that the front wheels had originally. If we now make a third experiment and lock the front wheels, the car will descend the incline slowly without skidding around.

The experiment made with this miniature car can be repeated with a full-size car that is equipped with brakes on all four wheels. When applying the brakes on the rear wheels only, if the car is running on a greasy road it will skid laterally; on the contrary, if the brakes on all of its four wheels are applied simultaneously, the car will stop without any lateral skidding. In addition to other advantages, brakes on all four wheels distribute the braking power on all four tires and thereby reduce the wear of the rear tires.

The Renault Braking System

The 18-30 hp. and the 40-60 hp. Renault cars are furnished with two sets of brakes. The hand brake acts directly upon the driving wheels only, but the foot-pedal brake exerts its retarding effort on all four wheels simultaneously. In each of these two braking systems, the operation is through internal expanding shoes in drums

[2] Vice-president, Renault Selling Branch, New York City.



fixed solidly on each wheels, the shoes or segments being expanded by the angular displacement of a cam.

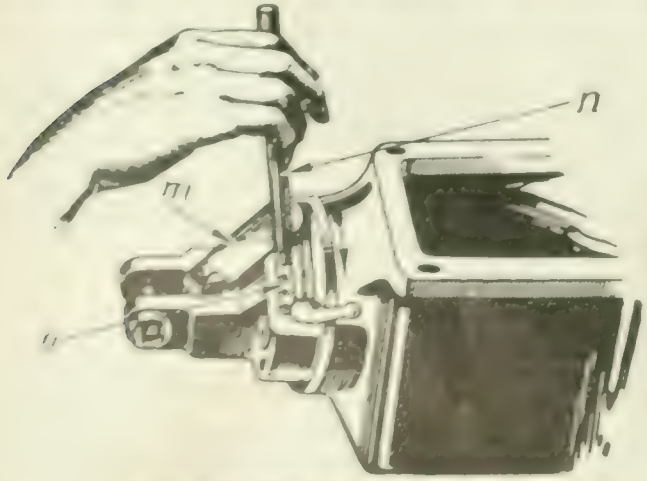
Fig. 4 is a sketch showing the layout of the servo-brake. It has three differential compensators. The main differential compensator, *a*, is used to equalize the retarding effort on the two front and two rear sets of brakes and it controls the two other differential compensators *b* and *c*, which equalize, in their turn, the braking force that is applied to the individual wheels. The main differential compensator, *a* and that which equalizes the front group, *c*, are situated under the floor-boards in front of the gearbox; the compensator for the driving wheels, *b*, is fixed on the torque tube, to the rear of the ball joint.

The brake cam-arms of the driving wheels are operated by rods of fixed length that connect them with the compensator shown at *b*. These rods are each supplemented by two other rods. The brake cam-arms of the front wheels are connected by two steel cables of fixed length that connect with and are controlled by the compensator shown at *c*. The brake-segment rods and cables between the two groups of brakes are regulated finally before they leave the factory; *they should on no account be altered.*

Principles of the Servo-Brake

Since the foot-pedal brake actuates the entire braking surface on all four wheels, the braking effort exerted on each wheel is always in accordance with the amount of resistance, or road-grip, of the wheels concerned.

Taking into consideration the great weight of the modern cars and the high speeds at which they travel, the physical strength of the average driver is not sufficient to apply the necessary force needed to obtain the maximum braking power. A normal man can only exert a force of about 130 lb. on a brake-pedal, and this allows for only about 45 lb. on each brake-drum. It is impossible to increase this pressure very much by levers and linkage, because the movement of the brake-pedal is limited to say 10 to 12 in. of travel. Further, at speeds of more than 35 m.p.h. the power needed for each brake-drum should be at least four to five times greater than the power a driver is capable of exerting. But the servo-brake system makes it possible for a driver to exert a very great braking pressure on each of the four brake-drums with very little effort.



This small amount of effort needed in the application of the servo-brake is due to the fact that the system derives its energizing effect from the movement of the car itself; therefore, it is obvious that the driver can obtain a very powerful braking force with a minimum amount of effort.

The hand-brake lever is moved alongside a ratchet, which can be regulated or set to produce the amount of braking effort required; to release the hand-brake lever, it is sufficient to raise the trigger from the ratchet tooth. This hand-brake lever first operates the differential compensator, *b*, in Fig. 4, and this equalizes the braking effect on each of the driving wheels.

Servo-Brake Description

The construction of the servo-brake is illustrated in Fig. 5, as well as the relations the parts bear to one another. The principles of its operation will now be described, by following in detail the manner in which the foot pedal functions.

The propeller-shaft *d*, running direct to the driving wheels, is connected through a worm and wormwheel, *e*, with the plate *f* of the servo-brake and revolves with it; therefore, it turns at a speed that is strictly in accordance with the speed of the car, but one much slower than that of the propeller-shaft. The second plate, *g*, is mounted upon a shaft so that it can be displaced longitudinally along the axis of the shaft, toward the plate *f*. Under the action of the brake-pedal, the rod to which it is connected moves the nut *h* which, in its turn, rotates the worm *i* in the same direction and thus controls the movement of the plate *g* axially. A "ferodo" disc, *j*, separates the two plates *f* and *g* in a manner similar to that used in clutch construction; when the brake-pedal is actuated to apply the brake and causes plate *g* to move toward plate *f*, the tendency is created to cause the plate *g* to rotate with the plate *f*; then, through the action of the compensating differential and its levers, *k*, the braking pull originating at the brake-pedal, which obtains added power due to the action of the plate-clutch *f g*, is communicated to the brakes.

Servo-Brake Adjustment

The "give" in the brake-pedal indicates the amount of play between the three discs *f*, *g* and *j*, in Fig. 5. When the ferodo disc *j* wears sufficiently, it is necessary to take-up this wear. The process of doing this is illustrated in Fig. 6. The two pins that hold the inspection plate *m* are removed, together with the plate. Then, with a punch, *n*, the collar *o* is turned in a clockwise direction according to the limit of the brake-pedal action, until no play exists between it and the controlling nut. The nut is then unscrewed one-quarter turn, corresponding to three divisions of screw holes. If, when this adjustment has been effected, the brake-pedal moves of its own accord, this is an indication that the servo-brake

has been adjusted too close; that is, the certain amount of play which is absolutely necessary between the three plates *f*, *g* and *j*, in Fig. 5, is not sufficient. It is then necessary to unscrew the adjusting nut another one-quarter turn.

Adjustment of Wheel Parts

As shown in Fig. 7, each brake-arm on the wheels of the car is fitted with an adjusting system composed of an endless screw that terminates externally in an hexagonal head, *p*, in conjunction with a toothed wheel that is solidly connected with the cam-arm *q*. The "taking-up" of the excess of play that might exist between the brake-shoes and the drums is accomplished by turning, in a counter-clockwise direction, to the extent of one or several teeth, the heads of the endless screws; the number of these turns must be exactly the same for each wheel, that is, to the extent of an equal number of teeth.

The adjustments having been made while the car is stationary, it should then be jacked-up completely and all of the car wheels should be rotated. If it then proves impossible to rotate the car wheels, the brakes are adjusted too hard and the four adjusting screws should be unscrewed to an extent that is *exactly the same number of turns for each screw.*

Hand Brake and Lubrication

When the hand-brake lever has been disconnected, the levers connecting it with the differential compensator should just protrude from the back of the case enclosing their upper parts.

The servo-brake should be lubricated with thick oil after every 600 miles of car travel. This is done by unscrewing the cap provided and refilling the reservoir to the indicated level,

Braking While in Reverse

A distinctive and important feature of the Renault servo-brake is that the driver can use his foot-pedal brake while the car is standing or goes backward. Again referring to Fig. 5, the shaft that carries the plate *f* carries also a ratchet device, *l*, the object of which is as follows:

The device remains idle when braking is being done while the car is traveling forward and during moments when the full braking force is required, but it permits braking when the car is stationary or in reverse gear; when the car is going backward, the plate *f* is free;

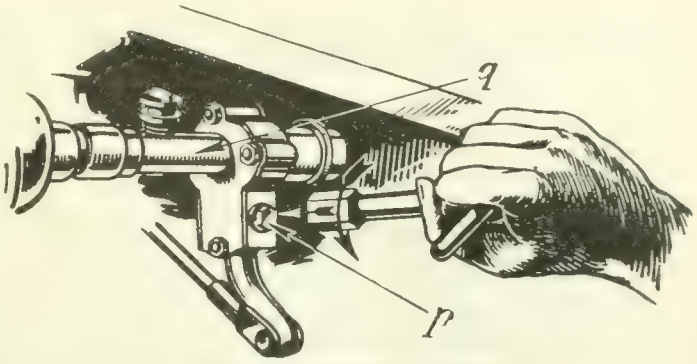


Fig. 7.—Adjusting the Wheels

because the ratchet device *l* operates. The brake-pedal causes the nut *h* to actuate the mechanism; the discs *f* and *g* rotate together because of friction, but they turn together independently of the propeller-shaft and as if the mechanism comprising the parts *h*, *i*, *g*, *f* and *k* constituted a set of compensating levers. It is true that in this instance the braking power is less than when the car is traveling forward but, in reverse gear, this more moderate braking power is wholly sufficient.

Operative Smoothness

In further reference to Fig. 5, the plate *f* turns at far less speed than that of the propeller-shaft *d*. In this manner, the heating effect due to friction between the plates *f* and *g* is reduced to a minimum.

Due to this reduction in plate speed and the extent of the friction surfaces, the wear on the ferodo disc *j* is very slight and a remarkable smoothness of operation is attained that is especially evident when making quick stops of a car that is traveling at high speed.

With the more perfect car control attained by using brakes on all four wheels that are actuated by a servo-brake, it is safer to travel at high speed and, therefore, the average speed that can be maintained is very much greater. This is also of advantage in city travel, through congested traffic, which necessitates continual stopping and starting.

After one has become accustomed to the use of four-wheel brakes on a car, to ride in a car equipped only with rear-wheel brakes gives one the same feeling of uncertainty that would be felt if one were to ride on a railroad train at express speed and knew that the train was not equipped with airbrakes on all its wheels.

STANDARDIZATION SAVING IN DOLLARS AND CENTS

THE $2,000,000 possible reduction in armature stocks estimated by A. H. Packer in his paper on Maintenance Effects on Automotive Electrical-Equipment Standardization, presented at the Chicago Service Meeting and published on p. 283 of the March issue of The Journal, raises points of much interest in connection with the maintenance of motor vehicles. The Society has standardized electrical-equipment mountings and the standards have been adopted in practice to a certain extent. The plans of the Automotive Electric Association, in furthering standardization, to establish standard sizes of generators and starting motors, warrant careful consideration by the industry. Standardization affecting the internal design of electrical apparatus is not considered desirable, but interchangeability of electrical units of different makes, as well as the reduction of sizes to the number of stock sizes of the units, could and should be attained.

CUTTING TESTS OF HIGH-SPEED STEEL

FIVE types of steel are to be considered in the investigation which is being conducted at the Bureau of Standards, and the second steel of the series has been heat-treated for the first set of tests in which hardening temperature is the variable. In connection with this work a number of treatments were applied to a single heat of high-tungsten low-vanadium steel to determine whether so-called fish scale or flaky fractures could be produced intentionally irrespective of the quality of metal as has been claimed. Normal fractures were obtained, however, in all cases, but these tests will be supplemented by further work with steels of questionable quality. The question was brought up for discussion at a recent meeting of the American Society for Steel Treating at Rockford, Ill.

Service from the Engineer's Viewpoint

By R. B. Bachman

Metropolitan Section Paper

After mentioning the operation of developing a piece of apparatus and pointing out that the analysis made by the designer is hardly likely to be as exact as that made by the production department, the author stresses the point that, while in some instances the designing engineer has laid himself open to the charge of being ignorant the service-man is not entirely blameless by reason of the impetuousness with which he makes and supports assumptions. For a designer to make and maintain personal contact with a large number of dealers is a difficult task.

In discussing the flat-rate system of service charges the author states his belief that undue merit had been claimed for the system and emphasizes the fact that it is not the only method which can be made satisfactory to the car owner. To be acceptable to the customer the price charged for repairs must appear to be fair and have as its basis an accurate method of determining the cost. Some flat-rate prices for service repairs of the most ordinary character are obviously unjustifiable. As opposed to these objections, the flat rate system is valuable in that it necessitates a careful analysis of the various operations. After commenting upon the variation in labor and time that sometimes results from the difference in individual conditions on the same class of job, the more serious matter of the variation in the amount of material required to do a first-class job under different conditions is brought out. In the author's opinion such variations cannot be properly provided for in the flat-rate system, with the inevitable result that the owner who is careful of his car is overcharged, while the one who gives less thought to the car's condition escapes with an undercharge.

In conclusion the thought is expressed that little or no demand has existed for economical transportation by automobiles as opposed to cheap vehicles and that a product based on the former demand would, in all probability, be a failure. However, in the near future the public will demand economy in automobile operation and this will be made possible by a number of factors, among which are the development of the highways, a widespread distribution of repair facilities, an increased knowledge of mechanical things and a greater ability to form a judgment as to true values.

THE need for service in the automotive field is such a self-evident proposition and has been commented upon so frequently that it seems unnecessary to do other than to indicate that I thoroughly appreciate its importance. It would seem to be inconceivable that of all the individuals interested in the automotive industry, there should be any that could more correctly appraise the value of close cooperation with the service organization than the engineer.

The operation of developing any piece of apparatus appears to be about as follows: The designer, having obtained information as to the purpose of the apparatus and a description of the conditions under which it is to function, will lay down a design based upon his experience. First, it will be necessary for this design to pass the criticisms of the manufacturing organization, particularly with regard to the accuracy of the various parts and the difficulties that an examination of the design indicates may be encountered in the pattern shop, the foundry or the forging department, as well as in the machine shop. At a later date, the design, either in embryo or in completed form, will be passed upon by the selling organization.

This analysis is hardly likely to be as exact as the production analysis. It is a matter of record that designs which were met with the most violent disapproval have, by their merit, proved successful. The relatively few cases, however, in which this is so are merely an indication that the factors entering into this particular part of the problem are not so susceptible of being given a definite quantitative value. It has been assumed in this hypothetical situation that there is no service department for the particular device in question, and this has been done purposely simply to point out that whether there be a service department or not, after these other analyses have been made during the period in which the design was being created, the final test of the suitability of the device is the service rendered in return for the price that is asked for it. The man responsible for the design, by whatever name you may call him, if he realizes the responsibilities that he must assume, cannot fail to recognize that it is only by observation of the manner in which the device meets the practical requirements of the user that he can check up the soundness of the original theory on which the device was developed.

Cooperation of the Engineer with Other Departments

It seems to be so self-evident that the engineer should put himself into sympathetic relations with all the various branches of the production organization, the sales organization, the accountants and the service department in order that he may properly develop any mechanism for which he is responsible, that I can do no more than most heartily endorse any reasonable suggestion for cooperation between the various individuals. There can be no possibility of excuse for the engineer not taking into consideration service reports, no matter in what form they come to him. It is only human nature that those suggestions which are presented in a helpful manner are most pleasant to consider. Recognizing this fact does not establish an excuse for neglecting to pay attention to information that may come in the form of querulous complaint.

With regard to details as to how this cooperative relationship shall be best established, it is exceedingly difficult to outline a method that will cover all requirements. It is obvious fundamentally that, as with most other things, personal contact is the most efficient method. It is, however, to be recognized that it is too much to expect that the service reports will always be complete and accurate, or that the recommendations made should always be followed blindly. Where the engineer can be justly criticised for his cold arrogance, the service-man can frequently be criticised for the impetuosity with which he makes certain assumptions and supports them. It must moreover be recognized that very frequently reports from two different service-stations are in direct opposition to each other; or it may be that alterations desired by the service department

conflict with design requirements as dictated by the sales or the production department. The engineer is therefore placed in a judicial position in which it is necessary for him to exercise his judgment in determining which of the conflicting viewpoints should be followed. Under such circumstances, it is probably not unnatural to suppose that the opinion of the engineer's ability and judgment will be lower in the minds of the individuals whose opinions have not been followed than it is in the mind of the one whose recommendation has been adopted.

This situation is, of course, another excellent argument for the establishing of those personal relations that always foster confidence between the engineer and the service organization, particularly. I think it is also worth taking into consideration while we are discussing this subject that it becomes a real man's job to get into and keep in personal contact with the multitude of dealers who form the service and selling organizations of many of our most widely sold cars. There are numerous ways in which the engineer can avail himself of information obtained from the service-station. It is unfortunate, however, that most of these methods depend for their highest efficiency upon personal study and interpretation. Where an exceedingly large volume of reports are received and must be digested, it becomes impossible for one man to handle the details. I have found it exceedingly difficult to train junior engineers to take the necessary critical pains in analyzing reports.

Objections to Flat-Rate Service-Charges

The flat-rate system of service charges has been discussed at great length and, while I believe that such a method possesses many features of merit, I am convinced that merits are imputed to the system which it will be hard to justify on careful analysis. One of these is the statement that the flat-rate system is the only method that will succeed in bringing the customer into a satisfactory frame of mind with regard to paying the bill. It seems that to have the price for work done acceptable, several things are necessary. First, the price must represent in the buyer's mind a just charge. I think that we can all point to a number of service jobs on an automobile where, even with the best of accessibility and with the best of facilities, the cost of a repair to the unskilled mind is out-of-line. These few cases can undoubtedly be adjusted by an explanation that will appear reasonable to the majority of men.

The second requisite is that the charge for the service performed be based on an accurate method of determining the cost, and this is not nearly so easy a proposition to determine as it might appear on the surface. I submit that if the service-man knows his costs and thereby establishes a fair price for the work that he performs he can obtain the confidence of his customer. Some flat-rate prices for service repairs of the most ordinary character are, on the face of them, absolutely unjustifiable. It appears that whether the customer gets this price before or after the job is completed is of little consequence, except that the service-man might get one job to do in one case where he would get none in the other.

The big value of the flat-rate system lies in the necessity, in establishing such a system, of making a careful analysis of the operations and determining with accuracy and certainty the cost of the operation. Such a process is recognized to be indispensable in the conduct of any manufacturing business, and is equally important in the service department, although to date the need has not been so generally recognized. Due to many conditions, it has been possible for service organizations to survive on a hit-or-miss basis of price-making that would have been suicidal in the manufacturing end.

Therefore, if the advocates of the flat-rate system, instead of placing emphasis on the results to be obtained from the system, would more strongly emphasize the preliminary investigations that must be made and the general business housecleaning that must be done to establish the foundations upon which a successful flat-rate system can be based, their purposes would be better served. Outside of the variation in the labor and the time that may result from the difference in individual conditions on the same class of job in the way of parts that are frozen and thereby consume a large portion of time to remove, the matter of the variation in the amount of material required to do a first-class job under different conditions is more serious.

I have never been able to see how these variations could be properly provided for by the flat-rate system unless an overcharge were made in some cases and an undercharge in others as a result of the application of the law of averages in establishing a price. This in itself is undesirable and becomes more so when it is realized that with this system the man who is overcharged is the fellow who has been careful and taken decent care of his car, and the fellow who gets the benefit is the one who has been careless and neglected it.

The Automobile as a Transportation Unit

It has taken a long time, relatively speaking, for the automobile to be recognized as a transportation tool. The process is just in its beginning. In the infancy of the industry, the vehicle was looked upon largely as a sporting proposition. Reliability was hoped for but not expected, and, until later developments in carburetion, ignition and tires removed many of the original elements of unreliability and delay, was despaired of. This statement, of course, does not minimize the developments that were made in general vehicle design and of materials in their application to the structure. This development, together with that in production methods which made possible the wholesale duplication of units with the consequent lowering of first cost, has made possible the volume of distribution that the automobile has had in these recent years.

There has been a demand for cheap automobiles, but there has been little or no demand for economical automobile transportation, which is an entirely different thing; and it is extremely probable that the attempt to produce and market an automobile based on such premises would meet with commercial failure. The engineer has been thinking for years about economy in operation, and is in possession of pretty definite information of the lines along which designs should be laid-out to obtain this economy. It has never been possible, up to this time, to get these ideas into practical form because they would not have met with public acceptance. There is no question, however, that within a relatively short time an increasing public opinion will be coming into existence that will be favorable to and demand economy in automobile operation.

Numerous factors will make this possible. Among them may be cited the development of the highways, the very general distribution of repair facilities, an increasing knowledge concerning things mechanical and a greater ability to form a judgment as to true value. As these factors develop and make their influence felt and become the basis for a new theory and practice in design and construction of automotive apparatus, some

that, by studying the repair work that is required on present-day automobiles, a vast amount of experience can be accumulated upon which the car of the future must be built to survive. [The discussion of this paper is printed on p. 95.]

SCIENCE AND ENGINEERING

(Concluded from p. 50)

mechanical power. We think usually of the solution of the problem of flight as an invention, as a revelation, granted to fortunate and gifted individuals. There is no doubt of the gifts of the individuals, but the striking thing is that this first flight was based on measurements made by scientific methods, even if only crude apparatus was available. These measurements were made after the previously published data were found to be inaccurate. The problem was solved by analyzing the factors involved, measuring the lift-drift ratio of different wing sections and different wing shapes, determining the elements of the problem of flight control and the necessary means for this control. We find the explanation for the fact that the Wrights learned to fly and never had an accident as a result of the failure of the powerplant, when we find that they analyzed the reasons for gliders going into tail spins and constructed a plane that could not go into a tail spin even if stalled.

All the facts regarding all inventions and discoveries would show that the results were obtained as the result of a more or less definite plan of investigation, and as the result of improved measurements, in many more cases than the public realizes. Science will give the engineer wonderful materials and wonderful processes in the future as in the past. Science can give the engineer today something that in the total will really be of more importance, a method by which the engineer can help himself, the scientific method of working. It remains for every engineer to decide how far he can make use of this method.

FRENCH COLONIAL EMPIRE

dominantly in the tropic or the sub-tropic regions. It goes without saying, too, that a very wide diversity of races is represented in these various colonial possessions, calling for a high degree of administrative skill on the political and the social side of their government; while the economic problems implied by the vast range of the products of the different colonies and the possibilities of advantageous development they afford are such as to call for the widest knowledge and the greatest intelligence on the part of those charged with the duty of coordinating the colonies with France herself in an economic sense and of binding the numerous members of this great empire together in one interdependent and mutually serviceable whole.—*Economic World.*

SOCIETY MEETINGS

LARGE ATTENDANCE AT SPRING LAKE

Meeting Attracts 748 to Atlantic Coast Resort—Low-Pressure Tires Featured

The 18th Summer Meeting of the Society was a distinct success. The attendance reached a total of 748, which is only a little shy of the record for Summer Meetings since their inception. Blessed with ideal seashore weather throughout the meeting period, every feature of the program was run off without interruption or postponement. The papers presented at the technical meetings drew large and representative audiences, their engineering value and timeliness were commended and the discussions were productive of valuable opinion on the debatable points. The numerous exhibits and demonstrations aroused more than usual interest and needless to say, the sports program brought out a large field of recreation lovers.

The sessions and informal porch meetings seemed to reflect a preponderance of interest in the introduction of large-section low-pressure air-cushion tires for passenger cars. Everyone present agreed that the advantages of this new equipment were sufficiently attractive to warrant a very thorough study and trial of the new tires to overcome the disadvantages that were cited against them. Some 10 or 12 demonstrating cars were provided at the meeting for the purpose of giving the members first-hand impressions of the improved riding quality resulting from the use of air-cushion tires, and these cars were in constant demand for curb-climbing and rough road demonstrations. It is evident that the tire engineers are not in complete agreement among themselves on the final design practice that will dictate sectional dimensions, air-pressures, rim widths and sections and other important fundamental data. They did reflect an optimistic attitude toward the eventual development of satisfactory low-pressure tires provided they can secure the full cooperation of car engineers in altering spring, steering and chassis design to take the utmost advantage of the air-cushion principle.

Four-wheel brakes, head-lamp glare and full problems also received attention at the technical meetings. The fact that four-wheel brakes can stop a car quickly was not questioned, but one judged from the discussions that many design points must be perfected before the use of this form of braking becomes universal. The danger of losing control of the car when only the front brakes lock seemed to be the chief point of discussion between the advocates of four-wheel brakes and those who are investigating them. That head-lamp lens design is being put on a more scientific basis was shown by the technical session and demonstration devoted to glare and road illumination. The Bureau of Standards' report on fuel volatility research, valuable studies made at Cornell University on the effect of spark advance and the Research Department's progress report on fuel research, filled the Friday session with interesting material.

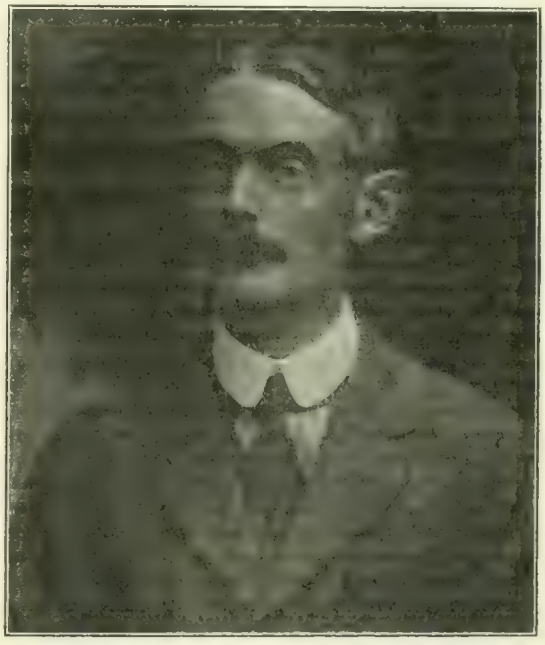
The following pages present a complete report of each of the meetings and all of the sports and entertainment. Nearly all of the papers are printed in full in this issue.

H. M. CRANE PRESIDENTIAL NOMINEE

Nominating Committee Announces Ticket of Society Officers for Year 1924

H. M. Crane was nominated to serve as president of the Society for the next administrative year by the Nominating Committee, which was completed and organized at the Spring Lake meeting. The committee reported the following other consenting nominees for the elective offices next falling vacant under the constitution, that is, after the 1924 Annual Meeting of the Society.

First Vice-President—E. A. Johnston
Second Vice-President, representing motor-car engineering—W. R. Strickland
Second Vice-President, representing tractor engineering—J. F. Max Patitz
Second Vice-President, representing aeronautic engineering—H. L. Pope
Second Vice-President, representing marine engineering—W. C. Ware
Second Vice-President, representing stationary internal-combustion engineering—T. B. Fordham
Councilors (to serve during 1924 and 1925)—J. H. Hunt, A. K. Brumbaugh, M. P. Rumney
Treasurer—C. B. Whittelsey



H. M. Crane Who Has Been Nominated for President of the Society for the Year 1924

The members of the 1923 Council who will hold over during 1924 are H. W. Alden as past-president and Councilors W. A. Chryst, F. W. Gurney and A. J. Scaife.

The Nominating Committee was constituted of F. M. Germane, chairman, member-at-large; Ernest Wooler, Cleveland Section; Lester Keilholtz, Dayton Section; George E. Goddard, Detroit Section; O. C. Berry, Indiana Section; C. F. Scott, secretary, Metropolitan Section; T. Milton, Mid-West Section; W. M. Newkirk, Pennsylvania Section; A. W. S. Herrington, Washington Section; E. P. Warner and E. H. Schwarz, members-at-large. A. W. Scarratt, Minneapolis Section, was kept in touch with the committee by telegraph. The members of the committee elected by the Buffalo and New England Sections were not in attendance.

This was the annual Nominating Committee, provided for by the Society's Constitution, under which 20 or more members entitled to vote may constitute themselves a special

Nominating Committee with the same power as the annual Nominating Committee. The By-Laws of the Society provide that a special Nominating Committee, if organized, shall on or before Nov. 15 present to the Secretary of the Society the names of the candidates nominated by it for the elective offices next falling vacant, together with the written consent of each

SOCIETY IN A HEALTHY CONDITION

All Reports Show Gains in the Past Year and Indicate Optimism for the Future

In opening the Business Session on Tuesday evening, President Alden expressed appreciation of the work of the members of the Council this year, stating that the average attendance at Council meetings had been good. He spoke briefly with regard to some major subjects to which the Society has devoted special attention this year, namely, highways, transportation and production. He said that the excellent Transportation Meeting held at Cleveland in April showed that the Society is getting in closer touch with the railroads and the electric railways, the railroad people cooperating in a commendable manner and a joint meeting of the Society and the American Electric Railway Association being proposed to be held at Atlantic City in October. President Alden felt that the highway research studies in which the Society is participating are proceeding satisfactorily. He said that the Production Meeting held in Detroit last October had proved very helpful.

With regard to financial matters, President Alden announced that, whereas during the last fiscal year and up to May of this fiscal year the expenses of the Society had been greater than its income, for the period of the current fiscal year ending May 31 a small unexpended income could be reported.

The office staff was commended for effective assistance in the work of the Sections of the Society.

The report of Treasurer Whittelsey reflected the steady growth in the income of the Society throughout the first 8 months of this fiscal year. At the close of business on May 31 last, there was an excess of income over expense of $878.33. At the same time last year there was a deficiency of about $18,000; that is, the net income for the present fiscal year has increased over $19,000 as compared with that for the same period of 1922. In the last score of years, it has been possible except during one year to hold the expense below the limits of the budget and maintain the income at a figure above the budget, leaving a surplus of from $10,000 to $30,000 for each year. Although not an organization maintaining activities for profit, from a financial point of view the Society is operated along the same general lines as a business house. At the present time, the income from members' dues constitutes about 50 per cent of the gross income of the Society, the other part of the gross income being derived from [illegible] advertising sales, interest on bank balance and investments, miscellaneous sales and contributions from affiliated organizations. The Society is proceeding on the sound policy that its income should be greater than its expenses during the years in which interest is increasing, to provide a surplus for periods of depression.

A comparison of the roster of members [illegible] shows that about the same number of members had paid their dues as of [illegible] May 31 last as had paid them at the same time last year. The total assets of the Society at the end of May amounted to $[illegible], about $[illegible] more than at the corresponding date of 1922. The income during the first 8 months of this fiscal year was $[illegible], the amount being about $[illegible] greater than provided for in the budget.

Lee S. Smith, chairman of the Membership Committee, reported a record up to that of the preceding year, stating that on June 1, 1923, excluding [illegible] the total number on the rolls of the Society was [illegible], the number of Student Members being 244 or more than last year. During the past year [illegible] members owing to death, resignation or the payment of dues. Notwithstanding this, the total membership is about the same in number as last year. It is considered that the membership is sounder as a whole from the standpoint of continuing interest in the work of the Society.

In connection with the report of the Meetings Committee, which was presented by Assistant General Manager Hill, President Alden asked for an expression of opinion from the members present as to the desirability of the Society holding a Carnival or a Dinner-Entertainment, similar to those of 1921 and 1922, during Automobile Show Week in New York City next January. A vote was passed indicating that it would be agreeable if the Council decided not to revive this event which was discontinued in connection with the 1923 Annual Meeting in New York City.

Harold W. Slauson, chairman, presented the report of the Sections Committee. He cited the following as among the most important actions of the Sections Committee and the Council this year:

(1) Continuation of the procedure whereby only members of the Society in good standing are eligible for membership in Sections

(2) The defining of territorial limits of the natural field of activity of each Section, these being the basis of appropriations to the Sections from the treasury of the Society

(3) The decision that the Society shall pay to each Section $3 for each Section member who resides outside the territory of the respective Section and not in territory allotted by the Council to any other Section. This is in addition to the Society payment to each Section of $2 for each Section member and $1 for each Society member residing in the respective Section territory although he is not a member of the Section

(4) Official announcement that the principal activities of the Sections being of a professional nature, the expenditure for social activities of Section funds derived from the treasury of the Society should be discouraged. This does not mean that the Sections Committee and the Council do not favor Section outings or entertainments, the expense of which is defrayed through some form of assessment paid by Section members as well as by guests.

(5) The establishment of standard requirements for the formation of a Section

Chairman Slauson announced that the Sections Bulletin issued from the office of the Society had greatly assisted the Sections Committee and the Sections officers, and in addition that the Sections manual is being revised with a view to condensing and making it more effective.

Mr. Slauson presented the following table of percentage of Society members in each Section territory who have become members of the respective Sections:

Section	*Per Cent*
Indiana	52
Buffalo	52
Detroit	50
Dayton	42
Minneapolis	41
Pennsylvania	38
Metropolitan	28
Mid-West	28
New England	24
Cleveland	21
Washington	21

Except in the case of the Buffalo, the Indiana and the Pennsylvania Sections, the figures above given have been computed from Sections reports made as of April 21, 1923. It is expected that the spirit of competition among the Sections will be increased not only in the matter of percentage of membership but also percentage of membership attendance at Section meetings. President Alden said that the Sections Committee had worked hard and done good work, the Sections now being in a better condition than before. He pointed

out that the Committee and office of the Society cannot alone do all that should be done in furthering the growth and value of the Sections and urged the members to support their Sections. He reiterated the statement that the life of the Society depends upon the sections.

Vice-Chairman Charles M. Manly, of the Standards Committee, reported upon the action of that Committee at its session held the same day. His report was approved. Mr. Manly protested against the making of unduly late criticisms of the reports of Divisions of the Standards Committee, stating that the lodging of various objections at the Standards Committee meeting after there had been an opportunity for months to express dissenting views amounted in his opinion to destructive criticism. He said that in view of the fact that the Divisions spend a large amount of time and thought in preparing their reports more consideration should be given them in connection with the tendency to refer back their reports in an offhand manner. He entered a plea for as much constructive criticism as possible in advance of the Standards Committee meetings.

STANDARDS COMMITTEE MEETING

The meeting of the Standards Committee at Spring Lake, N. J., on June 19 was convened by Past-President B. B. Bachman, and later presided over by Vice-Chairman Charles M. Manly. Committee and Society members and their guests to the number of 114 attended, which was very creditable considering the many attractive features of the resort that tended to draw the members from the meeting.

Of 28 reports submitted by 13 Divisions, 27 were approved in original and amended form, only one being referred back as a whole. This was the report on Engine Testing Forms, submitted by the Engine Division, which it was thought should be reconsidered in connection with several suggestions made during discussion. That part of the Nomenclature Division's report on Radiator Nomenclature which defined the several types of radiator core was referred back to the Division largely because of Herbert Chase's discussion. The Electrical Equiment Division's report on Magnet Wire, and the Parts and Fittings Division's report on Fuel and Lubrication Pipe-Fittings were withdrawn prior to the meeting.

The complete report of the action taken on all the reports, together with the pertinent discussion thereon and the names of those in attendance will be found beginning on page 79 of this issue of the JOURNAL.

A number of subjects were suggested for consideration by several Divisions, and these will be included in the schedules of work for the fall. It is not probable, however, that any meetings of Divisions will be called until the latter part of September, when official notice will be sent to all members of Divisions and Subdivisions as in the past.

JUNE COUNCIL MEETING

The meeting of the Council held on June 18 at Spring Lake, N. J., in connection with the Semi-Annual Meeting of the Society, was attended by President Alden, Past-President Bachman, First Vice-President Crane, Second Vice-Presidents Masury and Warner, and Councilors Chryst, Gurney, Scaife, Scott, Smith and Swetland.

The report of the Meetings Committee with regard to the Production Meeting to be held in Cleveland in October and the 1924 Annual Meeting of the Society to be held in Detroit next January was discussed. It was decided not to hold the 1924 Service Meeting of the Society in Chicago during the week of the Automobile Show.

Eighty-nine applications for individual membership were approved. The following transfers in grade of membership were made: Junior to Member, Claude S. Mobley, Arthur H. Rapp, Raymond W. Dwyer, E. Tasso Morgan, Herbert Joseph Howerth; Associate to Member, Howard L. Davis, Charles W. Wolfe, Herbert Scheel, W. H. Marty, N. R. Haas, N. J. Clausen, E. R. Jacobi, O. D. Heavenrich, Victor Jantsch, B. M. Leece, C. H. Paulsen; Junior to Associate, Raymond F. Buckley.

THE COUNCIL MEMBERS WHO ATTENDED THE MEETING

It was reported that up to June 15, 1923, 464 applications for membership and student enrollment had been received during 1923.

The following appointments to the Standards Committee were made:

Iron and Steel Division—J. D. Cutter.
Lubricants Division—H. J. Saladin.

The regulations governing the procedure of the Standards Committee were revised to provide that the letter ballot of Society members on adoption of standards shall be returnable 21 days following the publication in the JOURNAL of the action taken by the Standards Committee on Division reports. It is expected that this will save approximately 30 days' time in the issuance of new data sheets to the members of the Society. The present regulations provide for the counting of letter ballots 60 days following the Society's Business Meeting at which Standards Committee action is passed.

Rule 1 was amended to authorize the closing of the office of the Society at noon on business Saturdays during July and August.

The next meeting of the Council is scheduled to be held in September.

MEMBERS DISCUSS HIGHWAYS

Highways Committee Chairman Bachman Stages Discussion of Relation of Vehicle to Road

The meeting called by Chairman Bachman for Wednesday afternoon, June 20, at Spring Lake, N. J., was well attended. Some time ago Dr. T. J. MacDonald, chief of the Bureau of Public Roads, asked representatives of the automotive and rubber industries to attend a conference in the City of Washington to consider a program of highway research laid out by that Bureau. Much interest was shown in this program by a large number of members to whom copies were sent after the Washington conference. The object of the conference at Spring Lake was to afford an opportunity for a further discussion of those parts of the Bureau of Public Roads program that most concern the automotive engineer, and to formulate a definite policy regarding the relation of the Society to the Government's research program.

NATURE AND OBJECT OF THE TESTS EXPLAINED

A. T. Goldbeck, of the Bureau of Public Roads, explained that his organization is undertaking a series of tests "for the correlation of the motor vehicle and the road to promote the maximum economy in highway transportation." These tests involve the building of a stretch of road made up of slabs of different thicknesses of concrete laid on at least two types of subgrade. Vehicles of different weights will be run over this road and the stresses in the concrete will be measured

Society's Engineers Discuss the Program

In answer to a question by M. C. Horine of the International Motor Co. as to why the tests were confined to concrete roads, Mr. Goldbeck explained that concrete being a rigid material, it is possible to make stress measurements that would be impossible in other road materials. However, by measuring the stresses produced in concrete slabs by a given load of vehicles and determining the destructive effects of [illegible] on other types of road it is hoped to secure some reliable information on the loads that the latter type of road will sustain. It would be impossible to make tests on all the many classes of road, hence only a few typical constructions can be given special study.

Information gained through this research is needed by the highway engineers to permit the designing of roads to suit the existing traffic and types of vehicle, and by the automotive engineer and the tire designer to assist in designing vehicles and equipment that shall not impose excessive loads on the highways, both with a view to securing greater economy in highway transport. Mr. Goldbeck referred, in passing, to the research work which is being carried out under Professor Agg's direction at Iowa State College to determine the operating cost factors, fuel and tires as affected by highway conditions. Mr. Horine expressed a hearty endorsement of the Bureau of Public Roads' program as laid out and in doing so expressed the obvious sentiments of the entire conference.

In discussing the details of the program Mr. Horine recommended the inclusion of heavier trucks than originally planned and it was agreed that the heaviest types of stock commercial vehicle would be included in a chassis weight of [illegible] and that the load should include this weight. He recommended also that special attention be given to the effect produced on the road by empty vehicles traveling at high speeds, as this is a condition that increases maximum destructive effects on the vehicle and probably on the road as well.

Mr. Horine objected to the projected classification of solid and pneumatic tires together as one group, pneumatic tires forming another group. P. W. Litchfield explained that there are two types of cushioning, one that depends upon compressed air and the other upon the displacement of compressed rubber. Continuing the discussion of the effects upon the road of different types of cushioning, Dr. H. C. Dickinson suggested that for a given dead load these variations would convey just equal effects that can be determined by the roughness of the road surface. He felt that a study of the methods of securing and maintaining uniform roughness of road surface should accompany a study of impact effects on the road. President Alden stressed the point that the highway engineer's problem in designing a smooth road is parallel to the automotive engineer's problem in designing a vehicle so that it may have a minimum destructive effect and expressed the opinion that the road designer has caused as much damage to trucks as the truck designer has to roads.

The test road that was specially constructed for the purposes of this work is already complete and the Bureau plans to begin tests in about a month, according to Mr. Goldbeck, who appealed to the automotive engineers and to the representatives of the National Automobile Chamber of Commerce for cooperation. He wished the Society to appoint an observer to follow the tests and requested that the National Automobile Chamber of Commerce supply test vehicles, including a 7½-ton truck and one or more semi-trailers. Alfred Reeves, speaking on behalf of the latter organization, agreed to supply these vehicles and the Tire and Rim Association, through Mr. Litchfield, expressed its readiness to supply a man to assist in changing and taking care of tires.

Publication of Results Will be Handled Cooperatively

In discussing the procedure to be followed in publishing the results of the highway tests, H. M. Crane suggested that the cooperative plan by which the joint fuel research was handled by the National Automobile Chamber of Commerce, the American Petroleum Institute and the Society through a steering committee composed of representatives of all three organizations supplied an excellent precedent and should be followed in this case. The suggestion was adopted and the meeting closed with the appointment of Dr. Dickinson and Mr. Goldbeck as a committee to settle the matter of a whole or part-time representative of the automotive industry to supervise the tests.

LARGE-SECTION AIR-CUSHION TIRES

Problems Involved in Shoeing a Car with Low-Pressure Air

Despite the fact that the session held on the evening of June 20, 1923, had to do with the subject of low pressure, it was decidedly a high-pressure meeting that attracted members and guests enough to more than fill the grand ballroom of the spacious Essex and Sussex Hotel, and late comers had perforce to be satisfied with being spilled over to the adjoining verandas to peer through the doorways and French windows and hear the speakers as best they might. As a guarantee of smooth operation on low-pressure atmospheric conditions at high-pressure and great speed, Thomas J. Litle, Jr., was chairman and, following his opening remarks, he introduced the speaker of the evening, James E. Hale, of the Firestone Tire & Rubber Co., who presented his paper entitled "Shoeing a Car with Low-Pressure Air." The paper is printed in full in this issue of THE JOURNAL, but an outline is included herewith to further a better understanding of the prominent points developed by the discussion that followed its delivery.

Mr. Hale described the results of a deliberate attempt to make motor vehicles ride on air that is at a low pressure, through the use of an air-cushion tire having greater carcass flexibility than is usual and by enlarging the size of the tire section so as to provide a greater area of contact between the tire and the pavement. The goal tried for was to increase the area of contact sufficiently so that air pressures ranging from 20 to 35 lb. per sq. in. could be employed in actual practice.

The author first mentioned the fundamental conditions and this consideration was followed by statements as to what advantages the air-cushion tires containing air at low pressure give to a car. The effects on car operation were presented at some length, inclusive of considerations regarding car speed, steering ability, front-wheel shimmy, traction, braking control, blow-outs, punctures, side-sway and other factors of influence.

Durability and tire cost were treated in some detail, specific applications of air-cushion tires to automobiles were considered and a discussion of their desirability was invited. In conclusion, recommendations were made for a new tire-size nomenclature, in regard to oversizing and to tire-deflection limitation; and specific tire-size recommendations for air-cushion tires on stated makes of car were advocated.

Bumping the Bumps

In addition to the numerous lantern-slide illustrations, ultra-rapid motion-pictures were shown that slowed down the movements of two cars filled with passengers, one car being equipped with high-pressure pneumatic tires and the other with low-pressure air-cushion tires, so that comparisons as to their smooth-riding qualities over bad pavements were plainly, and, as shown by the jouncing of the passengers, sometimes laughably evident. The greater smoothness of car travel shown by the machine equipped with air-cushion tires, when operating over seriously bad pavement, was thus demonstrated.

System Applied to Discussion

The advantages of creating discussion by distributing cards throughout the audience upon which members write their questions and sign their names, as was done at a recent meeting in Detroit, were again demonstrated. The cards, after being collected, are presented to the chairman, who reads the questions in turn and requests an immediate answer from the author. In this manner a far greater number of questions can be asked and answered, the questions are stated more clearly and the subject is thereby given a discussion that is much more thorough and general. Chairman Little stated his hope that this system of discussion will be adopted generally by the Sections of the Society when holding future meetings.

The Questions and Answers

An outline of the queries of major importance is stated now by giving, in general terms, Mr. Hale's answers, the character of the query being implied rather than quoted verbatim. Mr. Hale said that the side walls of the 7.30-in. tire would not roll over onto the road when under a heavy car if the air inflation-pressure is high enough, and that the air-cushion tire resists "curb scraping" of its side walls better than the high-pressure pneumatic tire does. The suggestion of using the term "super-pneumatic" in place of "air-cushion" as a descriptive term it was thought by Mr. Hale should be referred to the Nomenclature Division of the Standards Committee. The running temperature of the air-cushion tire was said to be low, and that they hold their pressure better than high-pressure pneumatic tires do. He thought the provision of grooved treads for the air-cushion tire looks promising, but said that nothing had yet been done regarding the matter and that no tests of their application to passenger buses had been made. He said also that the comparative tests made of the air-cushion tires on taxicabs, referred to in the paper, were under identical weather conditions in April, 1923, while the taxicabs were running side by side. The query regarding vulnerability to punctures of the air-cushion tire was referred to the statements made in the paper, and it was said regarding how many air-cushion tires had been run to destruction that this information would be made available later.

The use of snubbers was said to be necessary when using air-cushion tires because of the excessive rebound they give to the springs, and the effect of deep ruts on the side walls was stated to be practically the same as for high-pressure pneumatic tires. The dust and stone-throwing ability of the air-cushion tires was acknowledged. An answer to the question as to the relative volume and weight of air in the air-cushion and in the high-pressure pneumatic tires was deferred.

Opinions From Others Who Were Present

Since so much time had been gained through using the question cards, time was yet available for further expressions of opinion, and Chairman Little therefore called upon representative members of the audience, by name, for critical comment. The representative of the Ross Gear & Tool Co., Lafayette, Ind., Mr. Chandler, referred to the engineering study of the subject his company has been making and said it had succeeded in producing a gear for use with air-cushion tire-equipment that is satisfactory. He considers the use of these tires as being involved with factors relating to steering, drag linkage, springs and the like.

J. E. Hale

T. J. Little, Jr.

Charles L. Nedoma, of the Cadillac Motor Car Co., Detroit, said that he had found the steering to be more difficult and that the liability to punctures of air-cushion tires was greater, citing his knowledge of an instance of six punctures of such a tire within 8500 miles of travel. Ernest Wooler, of the Cleveland Automobile Co., emphasized what Mr. Hale had said regarding skidding; he drove to the meeting in a car equipped with air-cushion tires and reported having made faster average time than did his companions who drove cars having ordinary pneumatic tires.

The statement was made by P. W. Litchfield, of the Goodyear Tire & Rubber Co., Akron, Ohio, that tire makers had been trying for a long time to persuade automobile builders to use tires of larger cross-section and lower air-pressure. It is a very delicate question, in his opinion, as to how far to go in this direction. He believes that tire rims should be made wider than recommended by Mr. Hale, and spoke of increased "shimmy" and steering difficulties when tire rims are too narrow. He mentioned a 5-in. rim for a 6-in. tire as constituting good super-pneumatic tire equipment, with an inflation pressure of about 26 lb. per sq. in. He cautioned tire makers that they must not get tire walls too thin, and said that great attention must be paid to attaining lateral stability.

Mr. Litchfield believes that there always will be times when conditions will demand "oversizing"; that is, a larger size of tire than is normal for a given equipment. Also, because of variations in wheel diameters and the like, tire sizes should be specified only in nominal terms such as 5-in., 6-in. and the like.

The representative of the United States Rubber Co., Hartford, Conn., S. P. Thacher, agreed mainly with Mr. Hale's statements but took exception to those referring to punctures and to power consumption. He favored a middle course with regard to cross-section and air pressures and said that, with "balloon" or air-cushion tires, the effect on the steering ability is bad because the wheel itself turns before the tire turns with it; that is, the wheel turns to the right or left, inside the tire, before the tire can follow it. He fears that the tire carcass may be made too thin, and said that he would be afraid to ride at 60 m.p.h. on tires having thin walls.

W. H. Allen, of the B. F. Goodrich Co., Akron, Ohio, believes the tire itself to be but a small portion of the problem and thinks that the other engineering factors involved constitute the greater difficulties. C. L. Moody, of the Fisk Rub-

[illegible] Co., Chicopee Falls, Mass., stated that he had nothing to add to what [illegible] had been said. H. W. Slauson, of the [illegible] Co., Cleveland, made brief remarks on the subject of air temperatures in relation to the amount of load carried by the tires. A representative of the Miller Rubber Co., Akron, Ohio, C. F. Ofeldt, said that his company favors a five hour run for automobile tires of approximately the same width of rim as is now used for ordinary pneumatic tires, when they are made tests.

In the closing remarks following the discussion, Mr. Hale said that differences of opinion with regard to all the factors pertaining to the air-cushion tire were to be expected, but that he was content to allow the statements made in his paper to stand as they are, without further comment. He mentioned the extremely rapid advancement in tire development that had occurred recently, and believed that whatever details may be right for tire construction will come into [illegible] eventually.

A most cheerful spirit of interest pervaded this evening session and, in the words of a prominent member who is best [illegible] to know, "It went over, big!"

ANNUAL FIELD DAY AN ACTIVE SPECTACLE

Races, Jumping, Throwing and Other Events Test Skill of Members at Spring Lake

The Annual Society Field Day at Spring Lake brought out many [illegible] fans and some few new ones. Engineer athletes exercised their skill in jumps, sprints and general muscular activity with hopes of collecting a share of the handsome prizes. The carrys-on were staged on the spacious lawn running along the seashore and the Atlantic formed a [illegible]. The entry list was slightly affected by the [illegible] activity of Old Sol's hot-spots, he being engaged in the business of creating new temperature records for himself in the environs of Spring Lake. Fortunately, cool breezes wafted in off the ocean and gave courage to enough [illegible] to make everybody happy.

The [illegible] events featured the baseball throwing contest as predicted by the fans. Our diminutive friend Buckwalter was in evidence in all events where avoirdupois is an asset. Miss [illegible] came all the way from Dayton with her [illegible] legs to show the ladies the way to the races set apart for the fair sex. The summary of results follows:

[illegible] Jr.:

It so happens that the lawn at Spring Lake is kept in [illegible] hue by a system of concealed sprinklers. After the field contests had been completed, the contestants were invited into the area of activity of these very efficient irrigators for the supposed purpose of receiving instructions from the officials. When all were watching the field director attentively, the pent-up activity of the sprinkling system was released with results that satisfied the humorous qualities of the gallery but that had a dampening effect on the spirits of the competing athletes. Thus ended the 1923 Field Day.

SECTIONS ROUND TABLE AT SPRING LAKE

Attendance, Collection of Dues and Local Membership Most Discussed Topics

Representatives from nine of the eleven Sections met with the Sections Committee and members of the staff interested in Sections administration for the Sections Luncheon at Spring Lake. President Alden assured the Sections representatives that the Council stands squarely behind any constructive work of the Sections, since the life of the Society is measured by their activities. Assistant General Manager Hill reminded the Sections officers that they are in the show business and that, like other showmen, they must choose topics interesting to their audiences, book speakers well in advance, advertise at least a week ahead

H. W. Slauson Hugh Chalmers O. A. Parker George T. Briggs
Part of the Sections Committee

in notices with a strong sales appeal, stage the meetings effectively, begin on time and end promptly.

Each Section represented contributed its experience for the benefit of the others. Cleveland believes that a Section should serve all Society members in its territory, whether members of the Section or not. The Dayton Section has been able to cooperate satisfactorily with the Dayton Engineering Society at a lower cost than it could work alone. The Indiana Section plans to maintain the interest already roused by securing good speakers in advance. National Society meetings offer excellent opportunities.

To make meetings more useful to those present, the Detroit Section plans to have its committee members seated together and tagged so that inquiries and suggestions will not go astray. Written questions for discussion of papers at meetings, in place of questions from the floor, save time and improve the type of questions asked. This Section went on record as favoring a contributing, purely local membership in the Section for men interested in the meetings, although not eligible for Society and Section membership.

The Metropolitan Section, serving a big membership with diverse interests, approves the suggestion that arrangements be made for "Section associates." The program for the coming year will cover operating problems. This diversity of interests and the wide area served by the Mid-West Section limit attendance at purely technical meetings. It is planned, therefore, to provide a year's program of three general, three technical and three special meetings to be addressed by prominent and popular speakers. Mid-West feels that while a general $5 increase in Society dues would limit Section membership and attendance at meetings, a $3 increase would be beneficial, if Section dues were omitted.

The Minneapolis Section finds that its distance from automotive centers makes securing speakers difficult. Attendance is another serious problem. The Pennsylvania Section also suffers from a diversity of industries in the large area served. Attendance at meetings is the chief difficulty faced, but joint meetings with other organizations have not been a satisfactory solution. Pennsylvania also approves some form of separate local membership in the Sections. The Washington Section, although situated in a difficult territory, believes that with staff assistance, it will be able to succeed.

Discussing the question of Section dues, President Alden emphasized the fact that increased Society dues in place of Section dues would be unfair to the more than 50 per cent of the membership who live outside territory which can be effectively served by the Sections. C. T. Myers suggested that dues be increased only for members living in Section territory as prescribed by the Council. George T. Briggs and Chairman Slauson believe the solution of increased interest in Section membership with consequent increase in dues paid, lies in securing A-1 papers and selling the value of Section membership intensively.

The roll of those present included

Herbert W. Alden	Lester S. Keilholtz
O. C. Berry	William E. Kemp
George T. Briggs	T. J. Litle, Jr.
F. F. Chandler	George L. McCain
Edward L. Clark	H. O. K. Meister
Coker F. Clarkson	Taliaferro Milton
Hugh R. Corse	C. T. Myers
T. F. Cullen	Phil N. Overman
H. E. Figgie	O. A. Parker
A. W. S. Herrington	Harold W. Slauson
C. E. Heywood	C. B. Veal
L. Clayton Hill	C. S. Whitney

Conrad H. Young

MEMBERS ARE KEEN SHARPSHOOTERS

Clay Pigeons Suffer Many Casualties as Shells Burst at Spring Lake Meeting

The clear blue sky above the Atlantic's restless surface formed an excellent background for the trapshooters to sight against at the Summer Meeting. The traps were set up on the beach directly in front of the two hotels and each day's shoot was watched by a large gallery of members. Many novices tried their luck with the double barrel and left the meeting as ardent clay bird spotters. A shoot was held each day and the finals were shot on Friday, with handicaps given the lesser lights based on their previous days' scores.

W. H. Miller broke 48 targets on Tuesday and took the prize for that day. R. S. Ellis won the Wednesday shoot with a perfect 50. The Thursday event was taken by H. P. Hobart, his handicap helping him to nose out Ellis. The championship shoot on Friday gave W. H. Miller a deserved medal, for he shot a perfect score of 50 from scratch. Ellis was second with 49 from scratch and Lon Smith took third credit with 47.

STANDARD HEAD-LAMP ILLUMINATION

Automotive and Illuminating Engineers and Legislators Discuss Common Problems

Indications point to a tendency on the part of State legislators to reconcile their laws applying to head-lamp illumination in such a way as to approach a reasonable degree of uniformity. The automotive manufacturer feels that head-lamp legislation is reasonable and just and is prepared to equip his vehicles so as to conform to these laws. In the few years that have elapsed since the Lighting Division of the Society's Standards Committee and the Society of Illuminating Engineers began their study of the head-lamp problem so much progress has been made that the only important task that remains is the education of the car builder and user in the essential facts brought out by the study of the problem. Representatives of the automotive industry, the State Legis-

DR. C. H. SHARP

R. N. FALGE

lature of New Jersey and the illuminating engineers all gave their views on lighting problems at the Head-Lamp Session on Thursday evening, June 21, at Spring Lake. The session was followed by a demonstration of head-lamp illumination, accompanying a short paper, staged by members of the Nela Park Research Laboratories' staff of the General Electric Co. This demonstration illustrated methods of measuring glare and of determining lens effectiveness.

ILLUMINATING ENGINEERS GIVE INTERESTING PAPERS

B. B. Bachman, who presided at the meeting, introduced R. N. Falge of Nela Park who read his paper entitled Importance of Better Automobile Head-Lamps and Proper Adjustment, which will be found elsewhere in this issue. Dr. C. H. Sharp made an address in which he gave a short historical review of the progress made in head-lamp standardization. Within the past year testing specifications for the approval of road lighting devices were formulated by the Lighting Division of the Society's Standards Committee in cooperation with the Society of Illuminating Engineers and had been submitted to State officials for their guidance. These specifications were approved by several States which agreed recently to approve only such devices as conformed to these specifications.

The testing specifications, as outlined at first, were very

The Legislator's Point of View and the Manufacturer's Problem

[illegible] Public Commissioner of the State of New Jersey, was represented by James J. Shanley, who described the pioneer work done by the State in eliminating the glare danger. New Jersey took action in 1922 to adopt the recommendations laid down by the two cooperating organizations and found them most effective. In expressing the Society's appreciation for the assistance they had received from the New Jersey legislative authorities in the difficult task of handling the road-lighting problem, Mr. Bachman called upon Alfred Reeves, general manager of the National Automobile Chamber of Commerce, to act as spokesman for the [illegible]

Mr. Reeves felt that the automotive manufacturer was well [illegible] with the State legislation regarding head-lamps and was anxious to cooperate to the best of his ability by equipping his vehicles in such a way as to conform to the requirements. It would be of great assistance, however, if he could be given time to adjust himself and his product to the rapid changes in legislative requirements. The fact that State Legislatures now differed so widely in their requirements did not tend to make the automobile builder's task any easier, but the tendency toward uniform requirements that Dr. Sharp predicted was a very hopeful sign. He would suggest that the States prepare a formula and allow the manufacturer to make his product in such a way as to conform to this requirement. He would also suggest supplementing this requirement of a formula by providing for some form of inspection in every State.

In the discussion that followed, A. D. T. Libby asked for information as to the most effective lens or lighting device on the market at the present time. The question was answered by E. C. Crittenden, of the Bureau of Standards, who said of the system that it is impossible to characterize any device as the best since the merit of any such device depends upon the driving speed and the personal taste of the operator. Many opinions had been received at the Bureau from people who favored a formula such as Mr. Reeves had suggested. He was strongly in favor of legislation of this kind provided the States demanded uniform requirements and administered the laws reasonably.

Importance of Adjusting Head-Lamp Devices

Mr. Crittenden brought out the point that a device which has been approved by State authorities may be almost useless if it is not properly adjusted. A recent test of [illegible] carried on regularly use in the City of Washington, which was made by the Bureau of Standards, had revealed the fact that of 400 cars tested, 5 to 6 per cent had improperly adjusted head-lamps, 4 per cent were dirty and 85 per cent glared. These came [illegible] equally to new cars. The garageman is in [illegible] to the adjusting of head-lamps; perhaps [illegible] If the garageman's good will could be gained by making it worth his while, one important phase of the required educational work would be accomplished.

The present practice of dimming head-lamps when passing or meeting another vehicle on a badly illuminated road was referred to by H. M. Crane who asked Doctor Sharp and Mr. Shanley for an opinion regarding the use of properly adjusted head-lamps on such roads. He felt with many other engineers that the dimming practice left the driver too unprotected and asked for information on the legislative attitude on this point. Mr. Shanley said in reply that there was no obligation on the part of the driver to dim his head-lamps anywhere in New Jersey and that there should be no necessity for dimming provided a proper device were used. Following out this idea, Prof. R. C. Gowdy, of the University of Cincinnati, gave a review of the road and laboratory tests made by him recently which brought out the importance of ditch illumination and the necessity for smoothness of lighting. He considered the problem of head-lamp illumination a very important refinement and one that closely concerned the automotive engineer. Much difficulty had been experienced with aiming and focusing light but it was felt that this no longer presented any serious difficulties. The session was followed by a most interesting verbal and optical demonstration of head-lamp devices and their operation by R. N. Falge and W. C. Brown.

HORSESHOE FLINGERS HAVE INNINGS

The presence of horseshoes at a meeting of automotive engineers does not seem to be fitting. However, due largely to the enthusiasm of A. D. T. Libby, this equipment was gathered together for a large group of slingers who tried to outdo one another as peg-ringers. A surprising amount of interest was shown in this time-worn pastime and one had to be clever to finish among the winners. H. N. Parsons proved to have the best eye. W. L. McGrath was second, and Booster Libby, who staged and ran the fracas, had to be contented with third.

FOUR-WHEEL BRAKES

For Usage by the General Public, Are They to Be or Not to Be?

The morning session held June 21 at Spring Lake, N. J., was devoted to lengthy consideration of the problems involved when brakes are applied to all four wheels of a car. President H. W. Alden was chairman, and a very representative audience of several hundred members and guests was assembled. In his introductory remarks, Chairman Alden said that the devotion of this session to the subject of four-wheel brakes had been decided upon only after due deliberation, and that the opening-up of this subject at this time had been voted opportune, although some comment had been made to the effect that it was premature.

The first paper presented was by Alvin M. Yocom, chief engineer of the U. S. Axl eCo., Pottstown, Pa., its title being Mechanical Braking on Four Wheels as a Present Automotive Necessity. The author stated that, when used in conjunction with the braking effect of the engine, two-wheel brakes work well in retarding a car on long or heavy grades but that, for emergency stops, by far the most frequent, two-wheel brakes do not give a driver the positive control of the vehicle and the sense of security that are imparted by the retarding effect of braking on four wheels.

The mechanical four-wheel braking system manufactured by the company the author represents was described and illustrated by lantern slides, the claim being made that the front-wheel portion of the system can be connected and equalized with any of the present-day rear-axle or transmission brakes without discarding any of the rear-axle or transmission brake-material. The equalization of brakes was discussed in some detail by the author, inclusive of foreign practice, and other features such as "fight" in the

brake-pedal, the mounting of the steering-arms and the distribution of brake-shoe pressure to prevent chattering and "grabbing" were treated at some length.

The paper by Marcel Guillelmon, vice-president of the Renault selling branch, New York City, was descriptive of the mechanical four-wheel braking-system of the Renault car. The advantages of its servo-brake mechanism in regard to braking power, smoothness of operation and adequate car control were set forth, and the lantern slides illustrating its principles were explained.

The author stated that the high car-speed demanded by present-day drivers of automobiles also demands braking systems that more adequately overcome the effects of such increased momentum than is possible with ordinary brakes applied only to the rear wheels. Since, at the time the brakes are applied, the greater part of the weight of the car is thrown upon the front axle and the front wheels, he believes it imperative that brakes be applied also to the front wheels, and that at car speeds of more than 40 m.p.h. it is unsafe to attempt to stop a car quickly if it is equipped only with ordinary rear-wheel brakes.

M. Guillelmon said that the editor of *Omnia*, Paris, France, showed very positively in 1921 that front-wheel brakes will prevent skidding, and gave a demonstration of this, using a toy automobile on an inclined plane that represented a steep grade. When the rear wheels of this little car were locked, the car ran down the incline and its rear wheels skidded slowly through a semi-circle until, at the bottom of the incline, they occupied the position that the front wheels had originally. When the front wheels were locked and the rear wheels were free to turn, the car descended the incline slowly without skidding around. The author stated that this demonstration can be made also with a full-size car that is equipped with brakes on all four wheels and that, if the brakes on all of its four wheels are applied simultaneously, the car will stop without any lateral skidding.

It is M. Guillelmon's experience that with the more perfect car control attained by using brakes on all four wheels that are actuated by a servo-brake, it is safer to travel at high speed and, therefore, the average speed of car-travel that can be maintained is very much greater; further, that this braking system is also of great advantage in city travel through congested traffic, which necessitates continual quick stopping. He said that after one has become accustomed to the use of four-wheel brakes on a car, to ride in a car equipped only with ordinary rear-wheel brakes gives one the same feeling of uncertainty and danger that would be felt if one were to ride on a railroad train at express speed and knew that the train was not equipped with airbrakes on all its wheels.

Owing to a most unfortunate delay, Malcolm Loughead, chief engineer of the Four Wheel Hydraulic Brake Corporation, Detroit, was prevented from being present at this session and so did not present his paper descriptive of the four-wheel braking-system actuated by hydraulic pressure that is manufactured by the company he represents. However, the paper was presented at the May 17 meeting of the Detroit Section, and a rather detailed summary of it was printed in the June, 1923, issue of THE JOURNAL on p. 611.

OPINIONS FOR AND AGAINST FOUR-WHEEL BRAKES

Following the call by Chairman Alden for discussion of the subject after the presentation of the papers, Charles L. Sheppy, chief engineer of the Pierce-Arrow Motor Car Co., Buffalo, said that tests and research work over a considerable period of time have shown his company that the application of front-wheel brakes to the average car of today cannot be considered safe. He stated that if the front-wheel brake has to be considered seriously for regular production, the following items should have serious consideration so that the application of front-wheel brakes will provide additional safety to the vehicle and not a menace.

(1) The front axle should be designed to withstand the torque due to front-wheel brakes

(2) Front springs should be of liberal width, should have an extra top leaf under tension, should have a center bolt to dowel into the axle, should be well supplied with rebound clips, should have the smallest possible arch under load and preferably a straight arch under load

(3) Spring bolts, spring clips and shackles should be of liberal size and of first-class material

(4) The cross coupling steering-rod should be straight, if possible, and, where spring-backed ball sockets are used, they should have a very limited amount of travel, preferably none

(5) The steering-pivot axle should have liberal bearing surfaces and be of such design as to withstand the additional stresses imposed by the use of front-wheel brakes. The steering levers should be kept as straight as possible and be of liberal sections and first-class material

(6) Bearings of sufficient capacity should be selected. The additional stresses on the front steering axles require serious consideration as to the loads imposed on front-wheel bearings

(7) The steering-gear operation should not affect the operation of the brakes, and the operation of the brakes should not affect the steering-gear operation in any way

Malcolm Loughead Charles L. Sheppy Marcel Guillelmon Alvin M. Yocom

THE AUTHORS OF THE THREE PAPERS PRESENTED AT THE FOUR-WHEEL BRAKE SESSION AND A PROMINENT FIGURE IN THE DISCUSSION

(b) Considerable interest should be given in regard to what interpretation the State authorities of the several States will place on four-wheel brakes as coming within the law of the States that require two independent and separate set of brakes

public, and voiced his belief that the industry should not allow itself to be rushed into four-wheel-brake production. He thinks that the industry should allow itself ample time to work out all the problems and thus make sure that when cars having four-wheel brakes are put on the market they will be as nearly perfect as engineering skill will permit. His reasons for advocating caution were stated in too great detail for reproduction here, but it is expected that they will be printed verbatim in a later issue of THE JOURNAL. He also rehearsed the possibilities of the transmission brake, and made pertinent comment on other important factors relating to the general subject of braking.

Chairman Alden said that the company he represents, the Timken-Detroit Axle Co., Detroit, is working on the four-wheel brake problem. C. T. Myers, consulting engineer, Rahway, N. J., stated his agreement, in general, with what Mr. Crane had said. W. G. Wall said that the die is already cast, since several makes of car now have four-wheel brakes. He favored these brakes but mentioned the difficulties of equalization and adjustment. He suggested the possibility that some other, such as a tubular, section may become necessary in place of the usual I-beam section for front axles, and was in general agreement with what had been said regarding difficulties of application. Joseph A. Anglada was in general agreement with what Mr. Wall had said. David Beecroft believes the subject affords the industry an opportunity, in that the automotive engineer should say whether four-wheel brakes are suitable for public usage, without domination or influence by sales considerations. M. Guillelmon, replying to a question, estimated that 75 per cent of European cars of 10 hp. and over have four-wheel brakes, because car speeds there are so great.

T. J. Litle, Jr., thinks that four-wheel brakes must come into being because most accidents result from poor brakes. He does not agree that they must have servo-mechanism, favors such brakes when equipped with external bands and believes four-wheel-brake difficulties are mainly those of proper equalization. L. H. Pomeroy discussed the theoretical differences between external and internal brakes; he mentioned the varying coefficients of friction that cause variations in the power of the wrapping type of brake and spoke of the necessity of having very rigid brake-drums and shoes for external brakes. He thinks the four-wheel brake will come into being in the United States and that automotive engineers should believe in it and develop it. P. W. Litchfield and C. M. Manly were also contributors of discussion pertaining to engineering aspects of the subject.

Following this session, demonstrations of cars equipped with four-wheel brakes of the types under discussion were made on the parkway in front of the Essex and Sussex Hotel; members and guests were thus given opportunity to ride in these cars and make comparisons of their braking ability.

METROPOLITAN IS CHAMPION SECTION

Takes Inter-Section Trophy for the Second Consecutive Year at Summer Meeting

Each of the members or teams winning a place in the sports events at Spring Lake collected a specified number of points which were credited to the Section he or she represented. The Section scoring the greatest point total was declared the champion for 1923. The scheme operates much the same as that used at intercollegiate track and field meets. It was started last year at White Sulphur Springs and promotes good-natured rivalry between the Sections of the Society.

When all the athletic battles had died away, it was found that Metropolitan Section had repeated its successful effort of 1922 and had won the cup for the second time. This was due largely to the New York monopoly on the tennis and swimming places, although some points were picked up in the other sports. The Detroit Section finished second and Cleveland was third.

The prize for ability as an all-round athlete went to Gor-

don Brown for the second time. His prowess as a water nymph carried him to the peak just ahead of N. G. Shidle, the tennis champion, and I. W. Danforth, the golfer.

FUEL-SESSION PAPERS AROUSE INTEREST

Lower Mileage in Winter with Heavy Fuels and Effect of Spark Advance Discussed

H. M. Crane, chairman of the Research Committee, opened the Session with a brief statement regarding the fuel-research program of the Society and introduced S. M. Lee, who presented the report of work accomplished at the Bureau of Standards since the Annual Meeting. This report, which is published elsewhere in this issue, includes a description of a series of road tests similar to those reported last winter, but less comprehensive in their scope and run under cold-weather conditions that confirmed the results obtained in warm weather. The author also gave a detailed account of the methods used and of the results obtained in the altitude chamber where conditions of air and jacket-water temperature are controlled and accurate records of performance can be kept. The results included a study of the specific consumptions of the test fuels under all conditions of steady running as regards load and speed, measurements of relative crankcase dilution with the different fuels and a brief statement of results obtained under conditions of acceleration. A further study of the latter and of the startling characteristics of the fuels is to follow.

The chairman, in commenting on the paper, explained that after the beginning of this research project about a year ago it was found necessary to educate the Steering Committee to the necessity of giving the men handling the details of the problem a free hand to follow out the lines of work that offered the most promise rather than to lay down a rigid program for the investigation. In the beginning the Bureau of Standards had been hampered by the rigidity of the program first specified, but for the last few months it had been given a free hand to investigate the particular conditions of operation that most emphasize the differences in performance chargeable to variations in the fuel. The results of this course are evident in the work accomplished, as shown in the report.

Heavier Fuels Show Lower Mileage and Higher Crankcase Dilution

A paper by Dr. H. C. Dickinson and John A. C. Warner entitled Winter Tests Show Lower Mileage on Heavy Fuels, which was read at the Fuel Session, will be found printed elsewhere in this issue. This paper gave the results obtained by the fuel-consumption and crankcase-dilution tests run jointly by 10 companies in cooperation with the Research Department. This program, which was substantially a repetition of the one put through last summer and reported at the 1923 Annual Meeting by V. H. Gottschalk, included the results of observations on a total of about 57 cars, covering 226 car-weeks of running, and a total distance of over 50,000 miles of running under normal service conditions.

The tests showed a small difference in fuel consumption between the different fuels, the heavier ones giving the lower mileage; a decrease of nearly 20 per cent in the miles per gallon for the same type of car, as compared with the results of the summer tests; an increase in crankcase dilution for the heavier fuels as compared with the lighter ones, and a decided preference on the part of drivers for the fuels having lower temperatures of distillation in the 10 to 20-per cent range of distillation, independent of the volatility near the end-point.

In commenting on this paper Mr. Crane called special attention to the marked preference of the drivers for the fuels of lower initial boiling range as illustrating how readily the average driver can be deceived as to what the engine really demands. The fuel marked □, which has the lowest end-point and is undoubtedly the best or next-best of them all so far as the engine is concerned, was third in order of choice of the drivers, apparently because of its higher initial boiling range.

Spark-Advance in Internal Combustion Engines

G. B. Upton's paper, entitled as above, was read by the author, who showed that spark-timing is one of the important elements in engine performance, which has received less attention than it deserves. The maximum economy of operation requires that the ignition should occur at such a time that the pressure rise takes place one-half before the dead center. This is found to require that three-quarters of the total explosion time shall occur before dead center.

The rate of burning and the total time depend upon both the speed and the load and a good automatic spark-control including both load and speed could increase the economy of service operation by as much as from 5 to 10 per cent. Such a device is practicable and should be less difficult of realization than correct mixture proportioning by the carbureter. The author proceeded with a study of the existing data on

S. M. Lee Dr. H. C. Dickinson

Authors of the Papers Presented at the Fuel Session

flame spread and deduced general conclusions as to the factors affecting it.

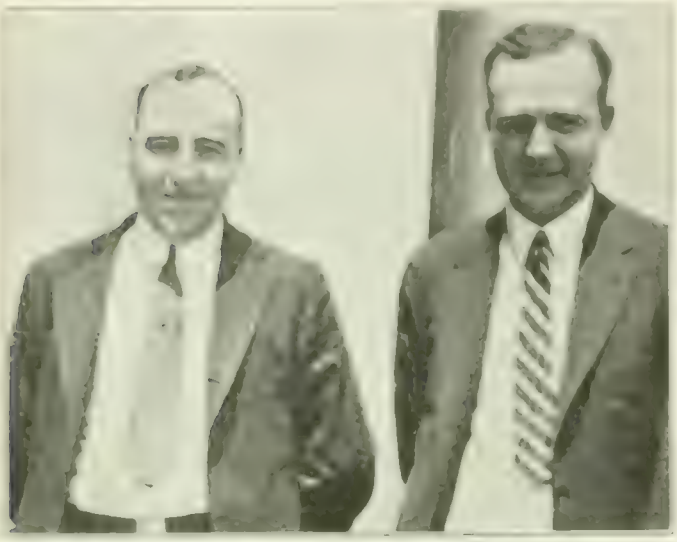
Professor Upton assumed the velocity of the flame spread to be proportional to the time; the distance is then as the square of the time. The assumption is for a typical valve-in-head combustion chamber from which the following conclusion is drawn: the volumetric rate of burning occurs at about three-quarters of the total time of burning. The pressure is slow at first, reaches one-half the total at about three-quarters of the time and drops off at the end. The author discussed the effect of turbulence, concluding that the effect is to produce a linear increase in the rate of flame progress. Engine speed has the same effect, turbulence apparently being proportional to the speed.

The effect of intake suction on the optimum spark-advance was shown by experiment to be independent of the speed. This means that speed and suction control can be made *independent*. The speed function, or the effect of the speed alone on the spark-advance was deduced from experimental results. Combining these two results, it is possible to deduce a turbulence function that may be useful in studying the turbulence effects of different cylinder designs.

The intake-suction effect on the spark-advance is found to depend entirely upon the dilution of the charge, and it is the mass dilution that is the controlling factor. An experimental result of considerable importance in the series of tests is, that the use of anti-knock up to 20 times the usual amount does not affect the optimum spark-advance.

Valuable Points Brought Out in the Discussion

In throwing the session open for discussion of the three papers Chairman Crane said that they all contained so much technical data that all should receive careful study to bring out the real points covered. Regarding the effects of spark-



the point that the mixture is usually ... earlier spark than would a normal mixture and ... decreasing the thermal efficiency already lowered at ... at part throttle.

..., Jr., took up the statement by the author in the latter part of the paper to the effect that the spark-advance required with doped fuels is the same as with normal fuels and stated that this contradicts the theory propounded ... that anti-knock substances reduce the rate of flame propagation. He said that the amount of tetraethyl lead used by Professor Upton was not abnormal; that for this amount ... great difference in spark-timing should be noted and that he would attempt to secure indicator-cards to show exactly what change in the timing is produced by the addition of ... knock substances.

O. C. Berry was gratified to learn that his own conclusions as to the importance and practicability of spark control for ... and lead were confirmed by a scientific ... He described at some length a spark control that he developed some time ago embodying these two features and said that the device was entirely successful, the greatest ... in the design being with the speed control and not with the pressure control, although the former is in ... use.

The greatest practical difficulty in the way of this development is the ... A number of existing patents ... the important features of such a spark control system, ... some of them covers enough of the features to serve ... as a basis for a successful mechanism.

S. W. Sparrow called attention to the very slow rate of ... combustion in the cylinder, depending upon the temperature, turbulence and other conditions at the instant of ..., and questioned whether any such arbitrary figure as ... of the total combustion time could be ... positively as the correct spark-advance.

In answer to a question by E. E. Wilson, Professor Upton ... that the rate of burning is entirely independent of the ... pressure of the charge. This has been shown for pressures ranging from 1 to over 100 atmospheres, the rate changing by a negligible amount over the entire ... The assumption that the flame velocity is proportional to the elapsed time, as shown in one of the illustrations, is ... correct as the rate is not a linear function of the time, but is nearly enough true for the purpose for which it is used, as fast as accurate as some of the other ... made.

Mr. ... results which he had found with one engine in which the optimum advance was 60 deg. for one plug firing alone and 35 deg. for two plugs at opposite sides of the cylinder, and Professor Upton stated that this exactly ... the statement in his paper that the time required for the flame to reach a given point is as the square root of the distance the flame has to travel.

Herbert Chase questioned the reasoning that is based on a definite total time for the completion of combustion, as presented by the author. This analysis refers to the completion of combustion as occurring at a time very shortly after the maximum pressure is produced. Mr. Chase called attention to the visible flames that always issue from an open exhaust at the end of the expansion stroke as an indication that combustion was not even then complete. Professor Upton thought Mr. Chase's eyes deceived him. Some chemical combinations, of course, do occur after the pressure peak and whatever flame may be seen is probably the result of an over-rich mixture or the high temperature of the exhaust.

Replying to a question of R. W. A. Brewer, Mr. Midgley stated that Professor Upton's conclusions checked with his own results. Discussing Mr. Lee's paper, Mr. Brewer suggested that exhaust-gas analyses would offer important additional information as to the relative behavior of different fuels. Mr. Lee stated that if the specific fuel-consumption is the same for two fuels it appears evident that any difference in the needle-valve settings serves only to compensate for the change in the viscosity. As an index to carbureter characteristics, exhaust-gas analyses seemed of insufficient importance to justify their incorporation in the report. Mr. Crane suggested, however, that any exhaust-gas analyses made should be included in the report.

H. L. Horning referred to Mr. Chase's question about afterburning and said that the most important problem is to eliminate afterburning by whatever means may be practicable. Turbulence is one means of digging the gases off the cylinder walls. Valve-in-head engines have little turbulence and require a long spark advance. An L-head engine may have the spark advance reduced from 35 to 4 deg. by a redesign of the cylinder-head. Spark-plug location is one of the most important factors. One interesting result of the fuel work was the data on the effect of viscosity. In cold weather the viscosity far overshadows the deficiencies of our apparatus in vaporizing. Mr. Horning also confirmed Professor Upton's conclusions that the spark-advance depends upon the amount of the exhaust gas.

DANFORTH IS 1923 GOLF CHAMPION

Tournament at Summer Meeting Draws Large Field and Produces Keen Competition

The largest field of engineering golfers ever gathered together in one tournament swarmed over the course of the Spring Lake Golf Club hoping to gather in the honors of being the Society champion for 1923. Close to 150 men played in the qualifying round, and since only 64 could continue in the several tournaments, it was necessary to be more than an ordinary devotee of the Scotch pastime. Nine cards of 90 or less were turned in and one of these was a 78. After the qualifying round the tournament was split into four flights, Championship, Class B, Class C and Class D, there being 16 contestants in each group. Winners in each class were determined by match play.

The semi-final round of the Championship Class found I. W. Danforth facing F. W. Davis and D. R. Meigs arguing with Alfred Reeves. Reeves and Davis succumbed, leaving Danforth and Meigs to fight it out for the medal. The match was a pretty one to watch, both men proving to be entirely out of the average class. The honors were eventually taken by Danforth and he is officially acclaimed the 1923 top-notcher.

G. S. Salzman, H. I. Hiatt, C. E. Dwyer and E. L. Vail worked through to the semi-finals in Class B. Dwyer and Salzman scrapped for the honors, the former winning 1 up in 19 holes. Joseph Bijur and B. S. Gier were the finalists

in Class C, Gier being the top man at the finish. Class D brought the 100 class men together for friendly conflict and J. B. Funk defeated W. H. Wallace in the final round.

Most of the golfers took free swings at the pellet in the man's driving contest on Friday. W. R. Flannery landed in front of all the others and Sanford Brown took second honors. The test of putting skill appealed more strongly to Sanford Brown and he nosed out C. T. Myers and C. H. Foster, who finished in that respective order.

The 1923 Golf Tournament proved conclusively that the Society must select a meeting place where golf facilities are ample. It was fortunate indeed that Spring Lake offered two 18-hole courses or the tournament never could have been finished in the allotted time without interfering with all the other events and meetings on the program.

Ladies' Golf Tournament

The golf tournament for the ladies revealed the fact that the lovelier sex are no mean wielders of mashie, driver and niblick. Mrs. George Case, the 1922 winner, was eliminated in the semi-final round by Mrs. Claude Foster. Mrs. George Lees defeated Mrs. F. E. Badger in the other set-to, leaving the finals to be decided between Mrs. Foster and herself. The laurels were eventually Mrs. Foster's in the final contest. The ladies' putting contest was won by Mrs. F. E. Badger; Mrs. Jack Gray was second and Mrs. George Case third.

ENGINEER NATATORS ASTONISH CROWD

Divers and Swimmers Have Great Frolic in Pool of Spring Lake Swimming Club

The Swimming Carnival at the Summer Meeting was the occasion for considerable splashing, spluttering and ripples. It would be considerate to say that a field of very fine swimmers appeared, but we must be truthful. The facts are that one or two talented research men did give indications of having crawled or trudged before but the balance must be placed in the "old swimmin' hole" class. Gordon Brown and Stephen M. Lee had a little series of two-cornered contests for the first two positions in most of the events. The stunt races tickled the large and appreciative gallery that witnessed the contests. A. K. Brumbaugh gave an all too short demonstration of the antics of youth in the children's pool. The representatives of the Metropolitan Section were after the first places in all swimming events to give them a second leg on the Inter-Section athletic trophy. The summary of the swimming events follows:

Watching the Swimming Events

33-Yd. Swim (Women)—First, Miss Betty Gurney; second, Mrs. Donald McKenzie; third, Mrs. Ernest Dickey

33-Yd. Swim (Men)—First, Gordon Brown; second, S. M. Lee; third, Rollin Abell

66-Yd. Swim (Men)—First, Gordon Brown; second, S. M. Lee; third, Rollin Abell

Balloon Relay Race—First, Detroit Section

Plunge for Distance (Men)—First, L. C. Hill; second, A. K. Brumbaugh; third, E. Y. Davidson, Jr.

Egg Race (Men)—First, Neil MacCoull; second, Gordon Brown; third, S. M. Lee

Candle Race (Women)—First, Mrs. Donald McKenzie; second, Miss Betty Gurney; third, Mrs. Ernest Dickey

Blindfold Race (Men)—First, Gordon Brown; second, S. M. Lee; third, Neil MacCoull

Fancy Diving (Men)—First, S. M. Lee; second, H. E. Butcher; third, E. Y. Davidson, Jr.

Plate Diving Contest (Men)—First, Gordon Brown; second, A. K. Brumbaugh; third, S. M. Lee

Night Shirt Race—First, Rollin Abell; second, Gordon Brown; third, S. M. Lee

Water Golf (Men)—First, S. M. Lee; second, Neil MacCoull; third, George Briggs

Section Championship Relay—First, Metropolitan (Gordon Brown, Sanford Brown, Neil MacCoull and Ira Snead); second, Detroit

Following the program of Society events Miss Eileen Riggin, youthful diving champion of the world, presented an exhibition of high and low board diving that was a delight to the eye. All of her dives were executed with uncanny precision and grace and put to shame her masculine imitators who had attempted to perform in sylphlike fashion with somewhat ludicrous results. All in all the aquatic program was good sport and seemed to please the spectators.

Of course the pilgrimage from the inland sections of the country took numerous dips in the briny and fluttered through the surf. It did not require much coaxing to frolic in the rollers with the temperature scale attempting to reach the century district. There is no denying the fact that Summer Meetings near the water have proved popular.

DETROITERS TAKE BASEBALL SERIES

Win from Harry Figgie's Clevelanders in Hectic Game Featured by Heavy Hitting

The Detroit contingent carried home the baseball cup emblematic of the championship for the year 1923. Neil McMillan, Jr., sprung the surprise of the meeting by organizing and captaining a nine that was able to take the measure of the well-groomed outfit presented by Harry Figgie. This upset prevented the Cleveland Section from taking their second leg on the cup.

The preliminary battles were played on Thursday afternoon. The Metropolitan Section inserted the novelty of having Miss Marie Luhring compete as a member of their nine. Miss Luhring is one of the few women who are members of the Society. The Cleveland crowd threw aside the customary courtesy shown the fair sex and proceeded to lay away the Metropolitan contingent to the unmerciful count of 14 to 2. The Detroiters then took the measure of

One of the Baseball Games on the Lawn

the Detroit Motor Boat assembly that had been coached and prepared under the expert tutelage of Joe George Briggs. The score in this preliminary was a little nearer being reasonable, the result showing 6—4.

The final game between the Detroit and the Cleveland Sections on Friday proved to be a contest crammed with exciting incidents. The Detroit outfielders, George Hunt and Tommy Jones, made many spectacular running catches that saved the day. Pitcher McMillan was engaged in a little pastoral recreation in the last inning when considerable business of importance was being transacted by the Cleveland batters. He offset his errors of omission by emulating one Norman Rush in the final period, neatly parking the indoor ball in the interior of a passing car for a complete circuit

Neil McMillan, Jr
Detroit

Captains of the Two Teams That Met in the Final Game of the Baseball Series

of the bases with two teammates preceding him home as company. The final figures given out by the disinterested score computer rate the relative merits of the teams at 8—7.

SHIDLE IS SOCIETY'S TENNIS CHAMPION

Also Takes the Doubles Championship with the Assistance of Herbert Chase

The tennis tournament at the Spring Lake Meeting drew out a larger field of entries than that of any previous Summer Meeting. There were many keenly fought matches and one or two upsets from preliminary predictions. Deuce sets and games were plentiful and few of the matches were mere set-ups. There were 20 contestants in the men's singles championship. The semi-final round brought Herbert Chase and Lloyd Clarkson together at the upper half, the latter winning 6—4, 6—1. Norman Shidle met Stanley Bates in the other half and defeated him 7—5, 6—4, after two very interesting sets. This left Shidle to face Clarkson in the finals on Friday. The first set zig-zagged for many games but finally fell to Shidle 7—5. This long struggle seemed to be the turning point in the match, for Shidle took the championship honors in the last two sets 6—1, 6—1.

Having teamed up to capture the doubles title and medals, H. M. Crane and C. F. Clarkson had little trouble moving through to the finals but Chase and Shidle were hard pressed by the Hunting Park combination, the final score being 6—4, 8—6. The finals were witnessed by a large and well-behaved gallery and provided some first-class tennis for the fans to applaud. Every set was contested warmly, but the youthful team of Chase and Shidle was not to be denied and galloped the latter to the tune of 6—4, 6—4, 6—2.

In the finals of the ladies' singles Mrs. C. F. Scott de-

The Tennis Players

From Left to Right They Are Miss Norma Porter, Runner Up in the Ladies' Singles; Mrs. C. F. Scott, the Winner, and N. G. Shidle, Winner of the Men's Singles and One of the Winners of the Men's Doubles

feated Miss Norma Porter 6—2, 6—0. The mixed doubles final was played by the teams Herbert Chase and Mrs. Ernest Dickey and C. F. Clarkson and Miss Ruth Porter, the latter winning on a come-back after the first set 4—6, 6—4, 6—4.

FIREWORKS SHOW FEATURES STUNTS

Metropolitan Contribution Pleases the Members and Townsfolk of Spring Lake

The credit for the most impressive Section stunt at the Summer Meeting goes to the Metropolitan Section. Its fireworks display on Thursday evening was the occasion of unnumbered ohs, ahs and ums from the assembled multitude. The citizenry of the Jersey coast resorts had been forewarned of the display by the local-gossip papers and there must have been 5000 people who enjoyed the pyrotechnic display. The engineering of this stunt must be credited to H. G. McComb, who planned and staged it with his customary efficiency. Rockets, bombs, pin-wheels, floral showers and attractive set pieces pleased the eye. The program was topped off with the display of the Society emblem in letters of colored fire.

The Dayton Section provided a small hydrogen captive-balloon on Friday for those who cared to chance a free ride over the beach. This novel stunt was conceived and carried out by L. L. Custer, whose perseverance was responsible for tracing through the tardy shipment of the material just in time to make good before the close of the meeting. The

H. G. McComb

Gene Fowler

Cleveland Section provided neatly embellished cigarettes at the dinner table to the delight of the members.

The Mid-West Section, reinforced by Phil Overman of Minneapolis and his tuneful banjo-mandolin, put over some acceptable Section harmony during the motion picture show one evening. The parodies used were pointed to indicate that the Chicago organization leads the world and all others are mere triflers. This claim met with some opposition, however.

The Section stunts are an important feature of all Summer Meetings and those presented at Spring Lake kept up the pace set in years gone by.

CREDIT WHERE CREDIT IS DUE

Mention of Those Who Helped to Make the Summer Meeting Successful

The Summer Meetings of the Society are successful largely because of the unselfish labor of certain members who devote time stolen from their own pleasures to direct the many activities. It is appropriate to give these members the credit due them as a part of this account of the successful gathering at Spring Lake, N. J., June 19 to 23.

T. Milton Who Managed the Entertainment Features

Mason P. Rumney, Who Had General Charge of the Meeting

TWO PERSONS WHO DID MUCH TO MAKE THE 1923 SUMMER MEETING A GREAT SUCCESS

First of all, mention must be made of the Meetings Committee under the able direction of Mason P. Rumney. This committee, with the aid of the staff at the New York City office, must handle the principal details of the program. T. J. Litle, Jr., E. P. Warner and O. C. Berry of the committee aided in securing a valuable set of technical papers. Taliaferro Milton managed the entertainment and ladies' events in commendable fashion.

THE STAFF OF THE *Daily SAE*

The comprehensive sport program required a number of willing workers, and they did a highly creditable job. The following members of the Sports Committee deserve mention for the complete success of the athletic events:

Sports Committee

Mason P. Rumney, *Chairman*
John Warren Watson—Golf
Lon R. Smith—Trapshooting
Walter J. Buettner—Tennis
Gordon Brown—Swimming
Neil McMillan, Jr.—Baseball
A. D. T. Libby—Horseshoes

The high caliber of the technical papers was mentioned favorably by all who attended the technical sessions. No attempt will be made to commend each author individually, but it should be recorded that their work of preparing and presenting the papers is appreciated by the Council of the Society. The Chairmen are thanked for their part in directing the technical discussions so that the greatest value could be got from them.

The International Motor Co. is thanked for its thoughtfulness in providing three of its latest type motorbuses to transport the members between the railroad station, the golf courses, the hotels and the tennis courts.

John W. Watson
Golf

Walter J. Buettner
Tennis

Gordon Brown
Swimming

Lon R. Smith
Trapshooting

FOUR OF THE MEMBERS OF THE SPORTS COMMITTEE

[illegible] Was Fitted with Tanks with Leaks in All of the Wheels

The head-lamp demonstration staged by the General Electric Co. was most instructive and valuable. It enabled the members to get a complete picture of the progress being made in perfecting anti-glare devices and the manner of applying the Society's head-lamp illumination standard. The United States Army exhibited two of its most recent transport vehicles and these were inspected by a large number of the members. The tire companies are thanked for providing cars equipped with large-section air-cushion tires so that the members had an opportunity to judge the improved riding quality resulting from the use of this equipment. Members were allowed to drive the cars personally to study the effect of the larger tires on steering. Cars of all sizes, from the Ford to the Lincoln and Cadillac, were provided for demonstrating purposes.

The companies who provided cars equipped with four-wheel brakes are thanked for their cooperation in the exhibit program. No formal demonstration was held, but the cars were available throughout the meeting period for members to drive and test as they saw fit. Stopping demonstrations were given by all of the cars immediately following the technical session devoted to the subject of four-wheel brakes. Unfortunately, they were brought to an abrupt conclusion by the interference of a conscientious Jersey State motorcycle policeman who arrested the Renault driver for traveling at a speed of 60 m.p.h. In another instance the local motor-cycle officials threatened the arrest of the driver of one of the low-pressure-tire cars who had been giving a demonstration of the curb-mounting abilities of his vehicle.

The *Daily SAE* a Clever Paper

The daily paper of the 1923 Summer Meeting was done very cleverly. The Motor Wheel Corporation was responsible for the presence of this newsy and spicy sheet and C. C. Carlton is specially thanked for this display of his interest in the Society and the meeting. The editorial staff was directed by Howard Spohn and E. C. Wright. Fred Wellman acted as chief of the production work and saw many wee morning hours of labor. Gene Fowler, humorist of the Hearst papers, wrote most of the humorous material and was largely responsible for the smiles noted on all faces at the breakfast table. Harry Tarantous, C. E. Heywood and others reported happenings in newsy fashion. The one big feature of the *Daily SAE* which seemed to make the biggest hit was the caricatures drawn on the spot by Henry Major, cartoonist of the Hearst publications. These were adjudged ace high.

One issue of the *Daily SAE* was sent to the entire membership of the Society to let them grasp the atmosphere of the Summer Meeting and decide to be numbered among the attendance in 1924.

SUMMER MEETING ENJOYED BY LADIES

Miss Cramer Again Captures Trophy in the Annual Dancing Contest

There was much ado at Spring Lake for the large representation of ladies present at the Summer Meeting. The social program in charge of Taliaferro Milton and the ladies' sports events left no time for twiddling of thumbs. Bridge tournaments were held each afternoon and attracted anywhere from 25 to 50 ladies. The first prize on Tuesday afternoon was won by Mrs. George E. Goddard, Mrs. E. W. Austin winning the second and Mrs. Ernest Dickey the third. Mrs. Jack Gray was the successful bidder on Wednesday afternoon, Mrs. W. J. Bryan and Mrs. R. S. Lane being second and third respectively. Mrs. Howard Spohn turned in the high tally card on Thursday, Mrs. Goddard being second and Mrs. W. P. Culver third. On Friday morning Miss Lois Culver was awarded the first prize and Mrs. George Kraus the second with Mrs. R. S. Lane running third.

The usual amount of interest was displayed in the annual dancing contest which was held on Friday evening. A large field of steppers competed and it took a long period to narrow them down to three or four of the better Terpsichorean artists. The crowd seemed to be evenly divided in their applause when the contest had narrowed down to two couples. After due deliberation, the judges awarded the first prize to Miss Catherine Cramer who was guided to success by Olney Jones. Miss Clara Wetzel of the Society staff was awarded second prize, her partner being Bernard T. Jones, also of the Society's staff. It was a trick of fate that both male partners in the finals should carry the uncommon name of Jones. Miss Cramer carries the dance trophy back to Detroit for another year.

The attention of the members is directed to an announcement of special importance regarding Part I of Vol. 17 of the TRANSACTIONS that appears on P. 124 of the advertising section of this issue of THE JOURNAL.

Standards Committee Meeting

THE reports of the 13 Divisions of the Standards Committee, which were printed on pp. 565 to 585 of the June, 1923, issue of THE JOURNAL were presented at the Standards Committee Meeting at Spring Lake, N. J., on June 19, and approved as presented or amended in the meeting or were referred back to the respective Divisions for further consideration. The action of the Standards Committee Meeting was approved by the Council and at the Business Session in the evening.

Under an approved revision of the Standards Committee Regulations, the letter ballot of the Society Members on final approval of the reports, will be returnable and counted 21 days following publication in THE JOURNAL of the action taken on them at the Standards Committee Meeting. The ballot on the following reports are therefore returnable to the Society at its offices, and will be recorded on July 23, 1923.

The usual letter ballot form will be sent to each voting member of the Society and will provide for affirmative and negative votes and waivers. Each subject to be balloted upon will be numbered to correspond with the numbers in the following report. In each case the following page references are to those upon which the reports were printed in the June, 1923, issue of THE JOURNAL. This issue should be used in connection with the following record of action taken at Spring Lake and in marking your letter ballot. Each time a ballot is taken there are a number of unsigned ballots returned to the Society, and as these cannot be counted it is suggested that every member casting a ballot read carefully the instructions that accompany it before returning it to the Society.

The following report includes only such changes as were made in the Division reports printed in the June issue of THE JOURNAL, referred to above, that were approved for submission to letter ballot by the members and the principal discussion of each subject in the Standards Committee Meeting.

AGRICULTURAL POWER EQUIPMENT DIVISION REPORT

(1) TRACTOR BELTS AND PULLEYS

(*June issue of* THE JOURNAL, *p.* 565)

AXLE AND WHEELS DIVISION REPORT

(2) FRONT WHEEL MOUNTINGS

(*June issue of* THE JOURNAL, *p.* 566)

The last three columns in Table 2 and footnote 1 were referred back to the Division.

THE DISCUSSION

C. C. CARLTON:—This report, although brief, represents the work of many meetings held by the Division and various sub-committees. Although objections have been made by some of the motor-car builders to the data incorporated in the report, the Division feels that the data conform very nearly to existing practice and that the report is worthy of adoption.

The question has been raised as to the number of flange bolts in wood-wheel hubs as given in the report. The R0 size conforms almost exactly to Ford practice for which six hub-bolts are recommended. For the other sizes of hub, 12 hub-bolts are recommended. Some of the axle manufacturers feel that 6 bolts are sufficient while others think that 8 should be used, but I am very sure that a large number of tests recently made over a period of 1 year particularly by the Hayes Wheel Co. and the Motor Wheel Corporation have proved to the satisfaction of every builder of wood wheels that 12 hub-bolts are necessary for good wood-wheel construction.

The Division, therefore, feels that although 6 and 8-hub-bolts are more nearly general practice today, 12 hub-bolts should be recommended.

On investigating the service department records of several companies using 12 hub-bolts we have found that their difficulties because of 12 hub-bolts are so much smaller than similar difficulties of those using 6 or 8 hub-bolts, that we believe this report is worthy of adoption as S. A. E. Recommended Practice.

H. M. CRANE:—Referring to Table 2, regarding the bolt size and the hub-cap thread I question whether it is not carrying standardization too far to use 12 7/16-in. bolts on four such different size hubs as are recommended, and whether the 3/8-in. bolt would not be ample for at least the two smaller sizes.

The hub-cap thread is plainly a compromise between what the size of the thread ought to be and the ability to use a cheap form of pressed hub-cap. These threads will hold all right if their fit is a good one and the hub-cap is reasonably stiff, but 24 threads for this kind of work is wrong, to my mind. Even 16 threads on the bigger hub-caps is too fine. I think 12 threads is what is really needed to do a first-class job.

Therefore, I move as an amendment to the motion to approve the report, that the number and sizes of bolts the footnote No. 1 and the hub-cap threads be referred back to the Division for further consideration.

MR. CARLTON:—Regarding the hub-bolts I have explained the feeling of those who were building wheels as to increasing the number of bolts to 12. Also by including the footnote "Machine Screw Bolts" we are trying to specify the best possible hub-bolt combination that a long series of tests has proved is what we want and that every builder of wood wheels favors.

Although Mr. Crane's criticism is correct, 12 hub-bolts are much better than 6 or 8. We have found that this is the weakest part of all wood wheels because the first thing that happens in failure is stretching of the hub-bolts. The hub-cap threads is the best compromise that we could make after studying a great many criticisms and suggestions received while drafting this recommendation.

MR. CRANE:—I cannot see why the R1 size hub should require 12 7/16-in. bolts if the same number of the same size are suitable for the R4 hub. I can understand why the wood-wheel makers would like to have them all alike, but it is my opinion that these hub sizes are too different to allow of using the same size and number of bolts. We have had broken front wheels having 10 3/8-in. bolts in which the hubs were not disturbed at all. I will admit they were fairly good bolts of good machinery steel.

GEORGE S. CASE:—I think the trouble in deciding between the 3/8 and 7/16-in. bolts is more a matter of trouble in assembly than the actual performance of the bolts afterwards. As bolt manufacturers we find that 3/8-in. bolts are very frequently broken with a wrench

MR. CASE:—If the report refers to machine-screw bolts

MR. CRANE:—Yes; all three columns.

MR. CASE:—Will the mover and seconder include that

CHAIRMAN HAUGHAN:—It has been covered, too, Mr. Case. The situation stands like this: a motion has been made and seconded that the report be accepted. Mr. Crane has moved to amend that motion to the effect that the last three columns headed "Number of Bolts"; "Bolt Circle" and "Bolting Thread" be referred back to the Division. Therefore if you accept the amendment and the original motion as amended, the report will be adopted without those last three columns.

There are a number of other combinations that it would be rather hard to get into. The first thing we want to do is to take a vote on the question of amendment. Do you wish to amend the motion to accept by eliminating those last three columns? Those in favor of the amendment say "Aye" opposed to the amendment "No." The "Ayes" have it and the motion is amended.

Now, we will take action on the question as to whether the report shall be accepted and the motion will be to that effect.

H. C. JEFFERY:—I would like to point out that if the number of bolts is altered it may change the bolt-circle dimension.

DR. CARLTON:—The Division has had a number of headings and they considered well on that account, but we were unable to specify the number of bolts that will suit a great variety of cases. The hub-size of bolts, which involves the axle manufacturer as well as the builders of wheels, fool that there is no one thing more important than to get something that can be standardized on this point. Those who want 6, 8 or 12 bolts of various sizes are represented on your list and it may be that we are attempting something impossible of accomplishment through the Society. This standardization is very desirable if it can be done.

ARTHUR J. SCAIFE:—Does the number of bolts have any bearing on the number of spokes used?

MR. CARLTON:—No.

MR. SCAIFE:—The bolts would then go through anywhere in the spoke butts?

MR. CARLTON:—Yes. As a result of the tests already referred to, those who felt that the bolts should pass between the joints of the spokes and those who felt that the bolts should go through the center of the spokes, have almost come to the conclusion that it is immaterial which way they go. The greater majority of the tests, however, show a very slightly increased strength with the bolts passing through the joints of the spokes, which is the reason for specifying the 12 bolts.

(3) Tenon Holes for Steel Felloes

(*Above issue of* The Journal, *p.* 566)

BALL AND ROLLER BEARINGS DIVISION REPORT

(4) Metric-Type Thrust Ball-Bearings

(*Above issue of* The Journal, *p.* 566)

THE DISCUSSION

F. W. GURNEY:—The Ball and Roller Bearing Division re-submits to the Standards Committee the matter of metric-type thrust ball-bearings, which it will be remembered was discussed at the last Winter Meeting. Most of us on the Division have felt that there was considerable misunderstanding then about just what we were trying to do in standardizing the metric-type thrust bearings that we recommended. There seemed to be a very prevalent feeling that the question of the metric and English systems of measurement are involved, but this is not at all what we have in mind. Unfortunately, the standards of ball bearings were first established in Europe, and for that reason they were laid out to metric dimensions. I think we all agree that if we could again lay out a suitable and ideal series of standards for ball bearings, we would make them to English dimensions. We are all working under the handicap of these metric standards that were established 15 or 20 years ago, but the whole industry is based and built upon those standards.

The metric-standard thrust bearings in the report are probably older than the English-standard thrust bearings that were adopted in 1917, I believe, by the Society. We think it is advisable to recognize that there are many companies using the metric bearings and about four firms that are manufacturing them. It is not a question of whether they are better than the others or whether they may be used to so great an extent as the others; it is recognizing the fact that they are being used and to make it more convenient for those who are using and manufacturing them.

R. G. CORNFORTH:—The report states that there were some 416,260 bearings of this type used per year. This is a small quantity compared with the total number of thrust bearings used in the automotive industry. As far as the completion of the S.A.E. Standard adopted in 1918 is concerned, it gives tolerance dimensions for the inside diameter. Is it necessary that we establish all the dimensions for these metric-type bearings? It rather looks as though we established limits and then want to draw these manufacturers into a very unusual standardization.

As for the necessity of having a standard of metric-type thrust-bearings for the users and manufacturers, I doubt very much if it will have much effect with them; they will not change their present designs to use the new bearings in their automotive work.

MR. CRANE:—As I understand it, there is already a partial standardization of the metric-type thrust-bearings printed on pages C39 to C42 of the S.A.E. HANDBOOK and a complete standard for inch-type thrust-bearings printed on pages C34 to C39. The proposal is simply to bring the metric-type thrust-bearings standard into line with the inch-type thrust-bearing standard by completing the already partial standard.

That being the case, it seems to me that the last speaker, if he wishes to be consistent, would move that the present partial standard of metric-type thrust-bearings be removed from the S.A.E. HANDBOOK. I cannot see any reason why we should have a lack of standardization in standards. If we have a certain form of standardization for inch-type thrust-bearings, we should have the same form of standard for the metric type if we are to have any standardization at all.

MR. GURNEY:—All we have now for the metric series is the tolerances that are given for ranges of sizes, while we have complete standardization of the inch thrust-bearings and merely tolerances for the metric series. The whole thing comes down to a question of fact; is the manufacture and the use of metric sizes of sufficient importance to warrant recognition by standardizing them? Are they being used to a sufficient extent so that the users of them need these standards?

MR. CORNFORTH:—Referring to what Mr. Crane said as to the partial standard that we now have, the tolerances are not of so great significance as might be considered, due to the fact that each maker or user will use whatever tolerances he feels are the best for his application of that type of bearing.

H. E. BRUNNER:—The point in connection with the partial standardization of metric thrust-bearings is that there are no standards, but there are in the S.A.E. HANDBOOK tolerances for them. These tolerances refer to those permissible for a given range of bearing sizes, but the standard does not specify what the sizes are.

G. R. BOTT:—This whole subject has been more or less misunderstood. There are some six or eight thrust-bearing manufacturers making metric thrust-bearings that have been used more or less for the last 20 years. It is their desire that these bearings be standardized to the extent that they can all manufacture standard sizes that will be interchangeable. This will help both the manufacturer and the user of the bearings. Originally the metric thrust-bearings were brought over from the European countries, about three makes of them followed one standard, the rest varied in dimensions.

A standard will make it possible for the user to avoid difficulty in the future in getting the same metric thrust-bearing from several manufacturers rather than to be confronted with the difficulty of using a bearing that is not standard.

There is no question of standardizing metric thrust-bearings as opposed to inch thrust-bearings. The manufacturer of metric bearings possibly also makes inch-dimension bearings. It is only a question of standardization. I for one cannot see why there should be any objection to the six or eight manufacturers of metric thrust-bearings getting together and standardizing thrust-bearings so that their tooling will be simplified and they will be able to carry reduced stocks to supply bearings to those who desire them.

Where metric dimensions control annular bearings, there is a desire sometimes to use metric thrust-bearings in conjunction with them. It would be foolish to eliminate entirely or refuse to standardize thrust-bearings because they are not used to such a great extent.

Let me repeat that there are some six or eight manufacturers making thrust-bearings and it is their desire to standardize so that the whole matter will be simplified. There is no question of compelling any one to use metric thrust-bearings in place of the inch-dimension thrust-bearing.

(5) METRIC-TYPE ROLLER BEARINGS

(*June issue of* THE JOURNAL, *p.* 567)

In Tables 4 and 5 the heading for the corner radii was changed to "Corner Radius of Cones" and a footnote added which reads "The corner radius of all cups shall be ⅛ in."

THE DISCUSSION

MR. GURNEY:—The metric-type roller-bearing dimensions reported conform in outside and inside diameters with the light and medium series of annular ball-bearings and the widths with those of the double-row ball-bearings, and are a revision of the standard already adopted by the Society.

T. V. BUCKWALTER:—These metric sizes are being made today in accordance with the tolerances in this table.

PRESIDENT H. W. ALDEN:—In the next to the last column of the tables which refer to "Corner radius, cups ¼ in., cones," perhaps the statement regarding the corner radius of cups would be better in the form of a footnote at the bottom of the tables rather than in the column headings.

(6) SHAFT AND HOUSING FITS AND TOLERANCES FOR BALL BEARINGS

(*June issue of* THE JOURNAL, *p.* 568)

ELECTRICAL EQUIPMENT DIVISION REPORT

(7) RUBBER BUSHINGS

(*June issue of* THE JOURNAL, *p.* 570)

Numbers for designating sizes were added.

THE DISCUSSION

J. A. KRAUS:—I suggest that numerals be used to indicate the sizes instead of the fractional diameters given in the table. I do not have in mind changing the design in the least, but being able to select from the list by number would facilitate purchasing.

W. S. HAGGOTT:—The suggestion to number the sizes in addition to giving the fractional diameters is good and there will be no trouble in doing so when the standard is printed in the S.A.E. HANDBOOK.

MR. CRANE:—I move, as an amendment to the motion for adoption, that the identification of this list of grommets by suitable numbers or letters be authorized at the time that it is published.

(8) CLIPS

(*June issue of* THE JOURNAL, *p.* 571)

The No. 22 gage for thickness was made minimum, and a note added under the table, which reads, "Clips shall be free from burrs and sharp edges."

THE DISCUSSION

F. W. ANDREW:—At a meeting of the Division this morning, it was decided to amend the report by specify-

(3) Cable Terminals

(*June issue of* The Journal, p. 570)

The [illegible] table in the [illegible] column on p. 571 was revised by the Division prior to the Standards Committee meeting in 1922.

[illegible]

[illegible]	Wire Size, A.W.G.	A	B	C	D
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] p. 571.

(4) Starting-Motor Mountings

(*June issue of* The Journal, p. 571)

ELECTRIC VEHICLE DIVISION REPORT

(1) Battery Trays for Electric Trucks

(*June issue of* The Journal, p. 571)

In the table under Fig. 1 on p. 572, the caption "Lead-[illegible] and that is to be specified intentionally. [illegible] in the second column in the table changed to "Range of Inside Widths or Lengths, In. Inclusive." The caption of Table 2 on p. 573 was changed to "Nickel-Iron Storage Battery Trays with Bottoms." The illustrations are to be amplified to show all cell compartments, including [illegible] which occur. The tray terminal arrangement [illegible] to be changed to show but one terminal in [illegible] the first tray in the upper row and the last [illegible] in the lower row.

(2) Charging Plugs and Receptacles

(*June issue of* The Journal, p. 571)

(3) Electric Vehicle Motors

(*June issue of* The Journal, p. 571)

ENGINE DIVISION REPORT

(1) Carburetor Flanges

(*June issue of* The Journal, p. 572)

FRAMES DIVISION REPORT

(1) Passenger Car Frames

(*June issue of* The Journal, p. 572)

IRON AND STEEL DIVISION REPORT

(1) Iron and Steel Specifications—Part IX

(*June issue of* The Journal, p. 572)

(2) Iron and Steel Specifications—Part X

(*June issue of* The Journal, p. 574)

LIGHTING DIVISION REPORT

(18) Bases, Sockets and Connectors

(*June issue of* The Journal, p. 580)

NOMENCLATURE DIVISION REPORT

(19) Radiator Nomenclature

(*June issue of* The Journal, p. 581)

The terms under "Group 2—Radiator" were approved but the definitions under "Group 3—Radiator Core" were referred back to the Division.

PARTS AND FITTINGS DIVISION REPORT

(20) Brake-Lining

(*June issue of* The Journal, p. 581)

The fractional negative thickness tolerance for the 1/4 and 5/16-in. sizes was changed so that it was expressed in the decimal form.

THE DISCUSSION

F. G. Whittington:—It is a matter of eliminating sizes that we find have almost eliminated themselves as far as professional practice is concerned, and revising the standard to include sizes that are being used extensively and did not appear in our list.

Vice-Chairman C. M. Manly:—Gentlemen, you have heard this portion of the report. Is there a motion for its adoption?

Mr. Crane:—I move its adoption, but I want to ask a question afterwards.

[The motion was seconded]

Mr. Crane:—Has the Division gone as far as I think it could in eliminating overlapping sizes?

Mr. Whittington:—The sizes in the report were verified by three brake-lining manufacturers at the last meeting of the Parts and Fittings Division, in whose opinion the sizes listed are necessary due to the present demand for brake-linings. We would, of course, like to eliminate all the odd sizes we possibly can.

Mr. Jandus:—I recall that there were real reasons for retaining all the sizes listed when the report was passed by the Division.

President Alden:—Why are the negative tolerances and no positive tolerance given for the nominal thickness?

Mr. Whittington:—Because the linings will almost always run under rather than over the nominal dimensions, due to the method of manufacture.

H. C. Mougey:—Why express the tolerances partly in fractions and partly in decimals?

Mr. Whittington:—We could change that to decimals.

Vice-Chairman Manly:—If brake-lining is usually measured with micrometer calipers when it is inspected the tolerances should be given in decimals. It is a question of trade practice, very largely.

Mr. Crane:—I would like to move an amendment to the effect that the Division be asked to make a further study of lining sizes with the idea that at the next meeting of the Standards Committee they may be able to report in favor of cancelling certain of the sizes given in this report.

R. S. Burnett:—This report is in the nature of a downward revision of the present standard, 10 sizes having been discontinued. In all likelihood when the Division makes a report on brake-lining testing it will take another step in the direction that Mr. Crane suggests.

(21) Rod-End Pins

(*June issue of* The Journal, *p.* 582)

(22) Cotter-Pins

(*June issue of* The Journal, *p.* 582)

The last sentence of the first paragraph of the introduction of this report was deleted.

THE DISCUSSION

John R. Reyburn:—The table in the report specifies no cotter-pin holes, but the introduction given above implies that a 1/16-in. cotter-pin goes in a 1/16-in. hole. I question whether the average cotter-pin will do so. We make a pointed-end type of cotter-pin and have always specified a clearance of about 0.0025 in. on the smallest size. It has been our experience that that is rather a minimum clearance and that for the average cotter-pin, which is not pointed, a larger clearance is required. I think in the past the most popular clearance for that size was from 0.006 to 0.010 in.

Mr. Burnett:—The question of specifying the drill sizes was carefully considered by the Division. The old specification listed "drill sizes." This specification was purposely prepared without any reference whatever to drills, the drill size being left entirely for the user to select according to the clearance that he wants in the hole.

Leonard Ochtman, Jr.:—It says here, "In submitting this recommendation, the Division contemplates that in case the report is approved, all other S. A. E. Standards and Recommended Practices specifying cotter-pins will be brought into agreement with this proposed revision." At present, as I recall, all of the standards and recommended practices specifying cotter-pins specify the size of the hole.

Mr. Burnett:—All of the standards referred to are for particular applications. The proper cotter-pin sizes and their drill sizes will be selected for each of those particular applications and so specified on those standards.

(23) Felt Specifications

(*June issue of* The Journal, *p.* 583)

The paragraph midway in the second column on p. 583 was changed to read "Unless otherwise specified, all of the above grades of felts," etc.

(24) License-Plates and Brackets

(*June issue of* The Journal, *p.* 584)

(25) Taper-Fittings with Plain or Slotted Nuts

(*June issue of* The Journal, *p.* 584)

TRUCK DIVISION REPORT

(26) Motor Truck Cabs

(*June issue of* The Journal, *p.* 584)

The following or a similar footnote was added under the table in the first column on p. 585:

> Inasmuch as the light duty or so-called "speed wagon" type and the heavy duty type of trucks are both made in the 1½-ton rated capacity size and equipped with either general class of cab, the selection of cab dimensions is optional as indicated in the accompanying table.

THE DISCUSSION

Mr. Crane:—Does the report intend that the 1½-ton size come under both classes?

Mr. Burnett:—The Division prepared the report that way purposely because it felt that very many trucks of the speed-wagon type and the heavy-duty type are built in the 1½-ton size, and wanted to leave the selection of either type of cab mounting open on the 1½-ton size.

Mr. Scaife:—At just about the 1½-ton size there is not a very clearly defined line as to what is a 1½ or a 2-ton truck at the present time.

F. W. Davis:—The Division felt very definitely that there are two types of 1½-ton trucks. One is the speed-wagon type to which Mr. Burnett has made reference. The other is the heavy-duty truck. Both types of cab are fitted to that capacity vehicle. It was purposely intended to include both the smaller and the larger sizes as applicable to that size of vehicle.

Vice-Chairman Manly:—It may be well to add a footnote stating that it is recognized as common practice in the truck field to use either cab size on the 1½-ton size and that it is so specified intentionally.

STATIONARY-ENGINE DIVISION REPORT

(27) Stationary-Engine Crankshafts

(*June issue of* The Journal, *p.* 585)

(28) Stationary-Engine Belt-Speeds

(*June issue of* The Journal, *p.* 585)

UNACCEPTED RECOMMENDATIONS

The following reports were referred back to the respective Divisions for further consideration toward presenting them again at the Standards Committee Meeting next January.

AXLE AND WHEELS DIVISION

Front-Wheel Mountings

The last three columns of Table 2 and footnote 1 on p. 566. [The discussion of this subject will be found on p. 79.]

ENGINE DIVISION

Engine Testing Forms

This report, which was printed in the June issue of The Journal on p. 573, was referred back to the Engine Division to consider several changes suggested in the discussion of the report.

THE DISCUSSION

Mr. Burnett:—The report on Engine Testing Forms is a revision of the present standard which has been contemplated for some time. It was completed about a year and a half ago, as I recall it, but was held up pending the report of the Lubricants Division on crankcase oil specifications, the temperatures of the tests being in question. The Lubricants Division has since made its report which has been adopted by the Society, and the engine testing forms have been changed to conform with that report. The few proposed changes and additions to the present forms and sheets as included in this report are submitted as a revision of the present standard to bring it up to date.

Herbert Chase:—The item at the end of the recommendation refers to the change in the ordinates for fuel consumption to read from 0.5 to 1.5 lb. per b.hp-hr. so that four ordinate lines will represent 0.1 lb. per b.hp-hr. It is very inconvenient to have four ordinate lines representing any even number because fractional parts are not easy to read along a curve. Also, as these forms provide for a test at light loads the fuel consumed in pounds per brake horsepower-hour is likely to exceed 1.5 lb. especially at very light loads, and I think on that account the ordinates on this curve should not be limited to 1.5.

result might be. Some engines with defective heat-distribution would show distinctly better performance at high than at low temperature. Using this form of test and operating at high temperature and correcting back might indicate an apparently much better performance than could actually be got under those conditions.

VICE-CHAIRMAN MANLY:—Would it not be a good thing to draw attention to the fact that these tests have been made at a particular temperature and that there is possibly a marked difference in performance at different temperatures? Snap decision would not then be made in comparing engines without checking up to make sure of their performance at various temperatures.

MR. CRANE:—If anybody wants to know what an engine will do at a given temperature, the safest thing to do is to test it at that temperature.

VICE-CHAIRMAN MANLY:—It might be a good plan in connection with the testing forms to call attention to the fact that the mere test at a particular temperature is not in any way conclusive as to how the engine will perform at any other temperature.

MR. CRANE:—It might be desirable to add a footnote to the effect that on multiple-cylinder engines this correction for temperature is frequently very misleading.

MR. CHASE:—Is it really significant in regard to testing the engine as to just what the viscosity of the oil is at the standard temperature conditions? They are not necessarily the temperature conditions of the oil that is lubricating the engine at the time, and it is the viscosity of that oil which has a bearing on the test results.

NOMENCLATURE DIVISION

RADIATOR NOMENCLATURE

In the report of the Nomenclature Division on Radiator Nomenclature, as printed on p. 581 of the June issue of THE JOURNAL, the Group 3-Radiator Core definitions were referred back to the Radiator Division.

THE DISCUSSION

MR. OCHTMAN:—Under "ribbon cellular core" at the end of the definition, it states "water passage." To bring this in conformity with the rest of the definition it should be changed to "fluid passage."

MR. CHASE:—I would like to suggest that the word "fluid" be eliminated in favor of "water," because the definition refers essentially to water types, the fluid in practically every case being water or largely water. I think the general term "fluid" should be omitted as it can be interpreted under certain conditions as meaning a gas.

MR. WHITTINGTON:—Inasmuch as gases are also fluids, why not have this definition read "liquid" instead of either "water" or "fluid"?

VICE-CHAIRMAN MANLY:—I think it was the idea of the Division that the word "fluid" being the broader term should be used, and I think it is entirely right so far as the nomenclature is concerned. Has there been any reason brought out why they want to separate a water radiator from an oil radiator?

MR. BURNETT:—No.

MR. SCAIFE:—Inasmuch as radiators are also used for steam, it seems to me that the word "fluid" would be in place. Liquid or water would not apply to steam.

MR. CHASE:—These definitions were originally framed and suggested by the Staff of *Automotive Industries*, and they were three in number instead of four. The matter was referred to the Radiator Division and the definitions that are here given were adopted by the Division.

I have held from the start of this subject that the

reason for this nomenclature is to make clear the difference between the types of core. I believe that the present definitions do not correctly define the cores as they are today, and that they admit of considerable confusion, especially the second definition.

I maintain that this definition applies equally well to the third type as defined here, for the reason that at least in some types of ribbon cellular core, so-called, they consist of an assembly of fluid tubes of several different cross-sectional forms, the tubes being joined together by radiating fins or plates common to all the tubes.

I have brought this matter to the attention of the Division and I have yet to receive a satisfactory reply to this particular objection. The original suggestions on this nomenclature did make it distinct and clear as between the two types. While I am not making a plea necessarily for the original suggestions, I do say that the nomenclature adopted should make it absolutely clear which type is referred to.

If you accept the word "fluid," I have no great objection, but I do object to the term "passages" when tubes are meant. An assembly of passages means little more than an assembly of holes, and one expression would be as nearly correct as the other. I maintain that this type of core is formed of tubes just as the other types are.

The continuous fin and tube type core is defined as "an assembly of fluid tubes of any cross-sectional form, the tubes being joined together by radiating fins or plates common to all the tubes." Some of the continuous fin and tube types are formed in groups of say six tubes. They are not continuous plates, however, and I think there need be no distinction between the individual and the continuous fin. If a distinction is to be made, it should at least cover all present types that are now in general use.

The definitions do not adequately cover the aircraft form of radiators, but refer chiefly to the types used on passenger cars, trucks and tractors.

W. P. KENNEDY:—I am not a member of the Radiator Division, but I do not think there would be any strong objection to leaving these definitions as they are with the prospect of interjecting others. One thing that occurs to me that is wrong here is with reference to where the plate is common to all tubes. Very few radiators are constructed where the plate is common to all the tubes.

MR. CHASE:—I think the matter should be referred back and these differences, which can be easily brought together, straightened out.

MR. KENNEDY:—Mr. Chase seems to think there is no differentiation between the two paragraphs. I think if they are read carefully they will stand out as distinctly different.

MR. CHASE:—I do not mean to say that there is no differentiation. I do say that the second definition covers distinctly the following one. In other words, if a continuous fin and tube core is defined in the way that it is defined in the report, it at the same time defines at least some types of ribbon cellular cores.

The primary reason for this nomenclature was to make a distinction between these types that are essentially very similar, and if this distinction is to be made, we should know when we speak of a continuous fin and tube core we mean what is generally understood to be that, and not something else that comes under the definition. The difficulty now is that two things are defined by the same definition.

MR. CRANE:—My point of view on this discussion is that the Division could work on this for a year and not produce a set of definitions that would not be open to misconstruction by the average engineer. If you asked him to tell you to which class a given radiator belonged, and then asked the same thing of another engineer, they would almost invariably put it in different classes. That will always be the way with anything that merges from one form into another the way the modern commercial radiator does.

MR. CHASE:—The fourth definition is the only one that is not open to serious criticism, as I see it. The first, second and third are incorrect from my point of view for the reason that they overlap more or less and are open to the trouble Mr. Crane mentioned. The fact that today one engineer will call a radiator a fin and tube type and another will call it the cellular type is the very point I make. The reason for this is that there is at present no standard definition. Unless the definitions can make such a distinction, and I believe they can, we might just as well not have them.

ATTENDANCE AT MEETING

The members of the Standards Committee and the Society and the guests in attendance were

Standards Committee Members

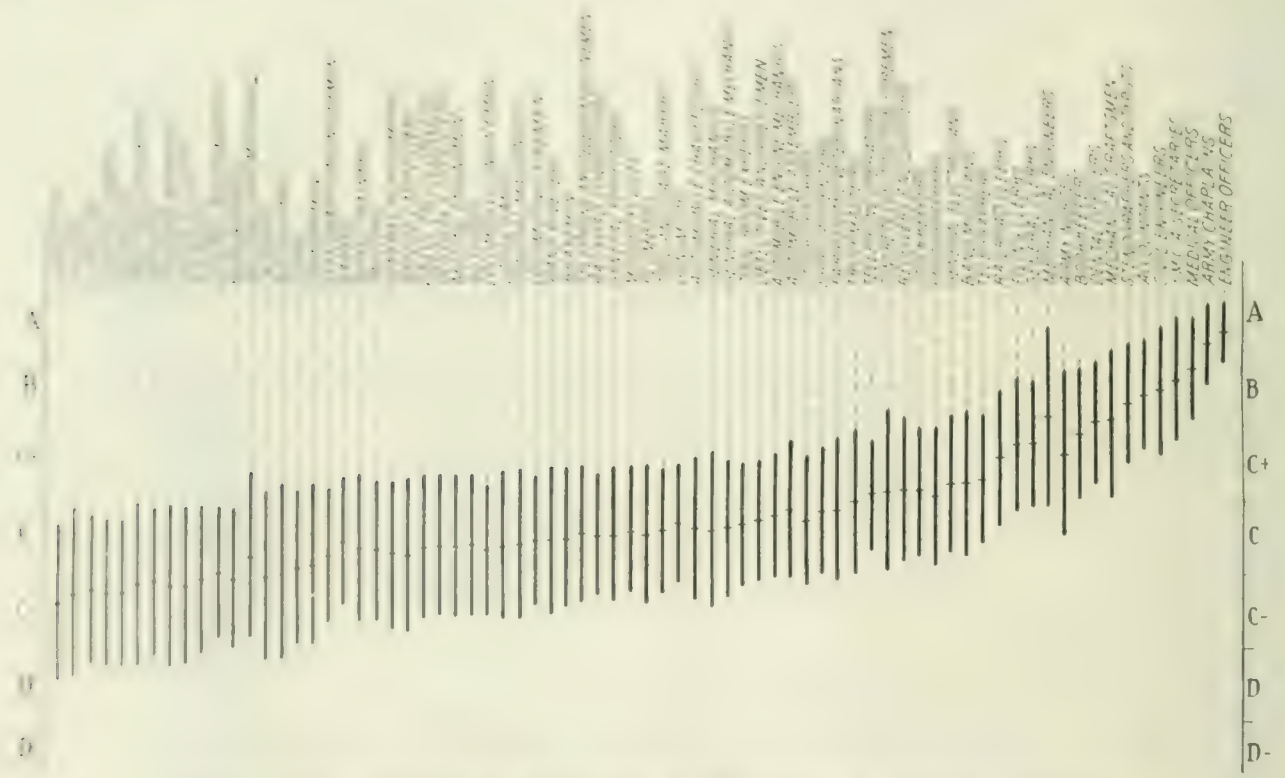
H. W. Alden
Azel Ames
F. W. Andrew
B. B. Bachman
George R. Bott
A. K. Brumbaugh
H. E. Brunner
T. V. Buckwalter
R. S. Burnett
C. C. Carlton
George S. Case
W. A. Chryst
E. L. Clark
C. F. Clarkson
H. R. Cobleigh
H. M. Crane
F. W. Davis
W. E. Dunston
George E. Goddard
W. E. Gossling
F. W. Gurney
W. S. Haggott
O. H. Hamm
George W. Harper
C. E. Heywood
M. C. Horine
Herbert S. Jandus
L. S. Keilholtz
William P. Kennedy
C. T. Klug
J. A. Kraus
B. M. Leece
A. D. T. Libby
C. M. Manly
H. C. Mougey
C. T. Myers
A. J. Neerken
John H. Nelson
W. M. Newkirk
George L. Norris
Leonard Ochtman, Jr.
O. J. Rohde
J. L. Rupp
A. J. Scaife
M. H. Schmid
C. W. Spicer
C. B. Veal
J. M. Watson
E. E. Wemp
James A. White
F. G. Whittington
T. H. Wickenden
Ernest Wooler
O. W. Young

Society Members and Guests

Rollin Abell
J. E. Andrew
Robert Atkinson
R. W. Ballentine
C. E. Banta
W. J. Baumgartner
A. C. Bergman
Willard C. Brown
C. W. Burrows
Herbert Chase
W. L. Carver
F. A. Cornell
R. Gardner Cornforth
T. F. Cullen
Luzerne Custer
James Dalton
L. R. Davis
Ernest Dickey
A. M. Dudley
O. E. Eckert
Russell S. Ellis
R. N. Falge
H. H. Gildner
G. Walker Gilmer, Jr.
A. N. Goodfellow
Crosby Gray
C. W. Hartenfels
E. M. Huggins
M. Lair Hull
R. P. Lansing
Marie Luhring
E. G. McDonald
J. F. Marshall
Albert G. Metz
Glenn Muffly
W. C. Munson
W. T. Norton, Jr.
Harry N. Parsons
J. O. Pierce
R. E. Plimpton
John R. Reyburn
O. C. Rohde
J. S. Schneider
C. F. Scott
R. H. Sherry
A. A. Skinner
Lon R. Smith
F. C. Stanley
G. E. Strohm
A. L. Swank
H. W. Sweet
M. George Tigar
Ralph H. Tyler
F. H. Walkley
E. P. Warner
J. A. C. Warner
H. G. Wilson
J. F. Winchester
Chase W. Wolfe

Engineers Lead in Army Intelligence Tests

THE Army Intelligence tests were devised during the war to measure natural capacity and intelligence, with a view to selecting for executive positions men who would derive the maximum benefit from army training. These tests did not attempt to measure a man's acquired skill or specific information. They relation between intelligence and occupation in the case of 36,500 men, was taken from a report of the office of the Surgeon General of the Army. Using the *D-A* scale at the top of the chart as a basis of comparison, the length of the heavy line following the title of each occupation indicates the range of intelligence of the men



engaged in it, while the short vertical line cutting the horizontal line shows the intelligence of the average man in each occupation. It will be observed that different occupations show different degrees of intelligence and that the class which holds highest rank in order of intelligence is that of "engineer officer."

WHAT "OUGHT" TO BE DONE

... foresees as "we" instead of "they," and realize that he is speaking and thinking of a group of individuals and not an abstract "it" or "they," the advancement of the profession through society efforts will be certain. Before the engineer can change the status greatly he must think and act as a citizen as well as an engineer.—From a report of a committee of the Iowa Engineering Society.

Winter Tests Show Lower Mileage with Heavy Fuels

By Dr. H. C. Dickinson[1] and John A. C. Warner[2]

Semi-Annual Meeting Paper *Illustrated with* Diagrams

SINCE the road-service tests of the four special fuels supplied by the Research Department, made under 1922 summer-weather conditions, gave results that were deemed inconclusive, arrangements were made for a repetition of both series of tests under the winter-weather conditions of 1923 to determine whether the relative fuel mileages for different fuels are dependent on the temperature at which car operation is conducted. The paper is a report upon the results obtained.

Four fuels that bore a relation to those used in the 1922 summer tests were specified and means adopted whereby knowledge of their quality was concealed from the drivers, special emphasis being placed on crankcase dilution and on general performance as reflected by the drivers' comments. The method of test was, for the most part, that of the summer of 1922, with cars operated as usual by their regular drivers, the filling with fuel and oil and the keeping of records being wholly in charge of the technical staff of the company concerned.

The details of procedure are presented, together with voluminous tabular data, and comment is made. A consistent and important decrease in mileage for the winter tests is apparent. The conclusions reached are stated in detail, as a summary, under six divisions.

LAST Summer 10 companies ran road-service tests of four special fuels specified by the Research Department and supplied by two petroleum refining companies, to determine the effect of fuel volatility on the average mileage per gallon of fuel, under normal service conditions. These results were reported at the 1923 Annual Meeting of the Society as part of the general research program in which the Society is cooperating with the National Automobile Chamber of Commerce, the American Petroleum Institute and the Bureau of Standards, and have been reported from time to time in The Journal.[3]

The reports of the tests run by the companies under summer weather conditions showed, as did the Bureau of Standards tests, the unexpected result that volatility of fuel within the range tested had no appreciable effect on the fuel consumption per mile, but did have a marked effect on crankcase dilution, the heavier fuels being far worse in this respect than the lighter ones.

It was generally agreed, after the presentation of the results by the Bureau of Standards and those of the service tests of the 10 companies by the Research Department, that such tests run under summer weather conditions were inconclusive as regards year round operation when common experience indicates that heavier fuels are more difficult to handle in winter.

Arrangements were therefore made immediately after the Annual Meeting for a repetition of both series of tests under winter weather conditions to determine whether the relative fuel mileages for different fuels are dependent on temperature of operation and, if so, to what extent.

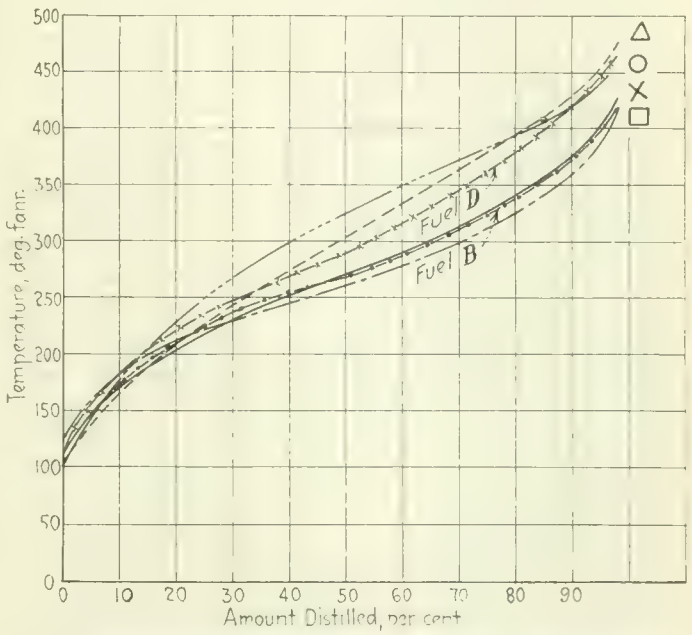


Fig. 1—Distillation Curves of the Four Fuels Used by the 10 Automobile Companies and of the *B* and *D* Fuels Used in the Bureau of Standards Tests

To repeat the series of tests by the several companies required all possible speed in making preparations and securing the necessary supplies of special fuels. The cooperation of the American Petroleum Institute, of the Atlantic Refining Co. and of Cosden & Co. made it possible to get fuels supplied to the 10 companies that agreed to run the tests, in time to complete the work before warm weather came. The universally late spring this year is to be credited with part of the success in this respect.

Fuels

A discussion of the summer tests by the committee in charge of the general fuel-research program resulted in a request by the refiners that the winter tests be arranged so as to make possible a comparison of the behavior of fuels with different initial-points as well as those with different end-points. Accordingly, it was decided to specify four fuels having the following relation to those used in the Summer tests: one fuel identical with fuel *B*; one identical with fuel *D*; one with the same 90-per cent point as *B* but with a lower 10-per cent point; and a fourth with the same 90-per cent point as *D* and with the 10-per cent point like that just mentioned. Further discussion developed the opinion that only very moderate changes in initial-point are practicable. The four fuels finally delivered did not meet the specifications as nearly as was desired but had to be used for lack of time to have

[1] M.S.A.E.—Manager of research department, Society of Automotive Engineers, Inc., New York City.
[2] Assistant manager of research department, Society of Automotive Engineers, Inc., New York City.
[3] See The Journal, January, 1923, pp. 3 and 118; also February, 1923, p. 139.

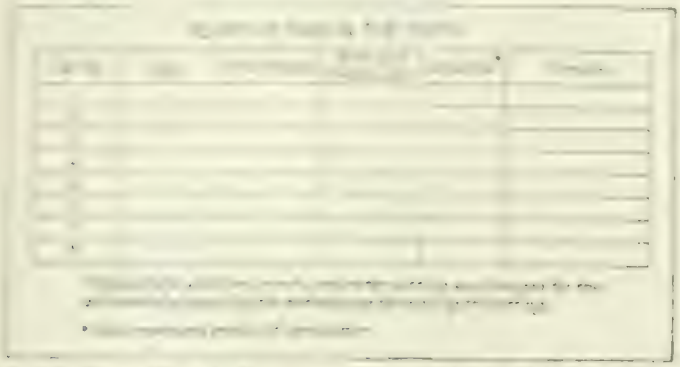


Fig. 1—[illegible]

[illegible] used. The distillation curves of these fuels are given in Fig. 1.

In planning the new series of tests special emphasis was laid on crankcase-oil dilution and on general performance as reflected by the comments of the drivers. In order that such comments may have any real significance, it is, of course, always necessary to eliminate any possibility of prejudice on the part of the driver, as the best observer in the world cannot avoid some degree of prejudice if he has previous knowledge of what is to be expected. Some plan was necessary, therefore, by which the four test-fuels could be identified without giving the drivers any hint as to their characteristics. For this purpose the symbols □, ×, O and Δ were used as shown on the foregoing figure. This system of symbols, together with the fact that in general the distillation curves of the fuels were not sent out until the tests were practically completed, and distillation curves were not made by the several companies until the tests were completed, make it safe to assume that the opinions expressed by the drivers are entirely free from any preconceived ideas as to the fuel characteristics, and are a reliable index to performance, so far as they go.

The engineers of the several companies were asked to keep a record of the oil consumption as well as of the fuel consumption, and to send samples of fuel, of new oil and of used oil from each car at the end of each week's operation to the Bureau of Standards for test. The number of these samples being over 200, only a part of the test results are as yet available and the present report is incomplete in this respect.

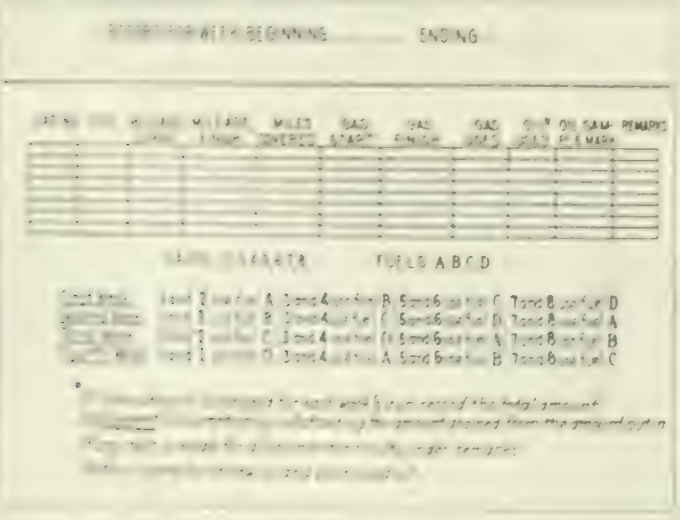


Fig. 2—[illegible]

The method of carrying through this program was the same as for that of last summer except as noted above, that is to say, for the most part the cars were run in groups of 4, 8, or 12. They were selected from among those driven by employes of the companies, either as owner-drivers or regularly employed drivers in the company service. They were operated as usual by their regular drivers without any special reference to the test under way, except that the filling with fuel and oil and the keeping of records was handled entirely by the technical staff of the company. In each case, the group of cars was divided into four units of one, two, or three cars each, and each unit operated on each of the four test-fuels for one-week intervals, the test thus requiring four weeks with the schedule so arranged that all fuels were in use at all times in an equal number of cars, and that every car used each of the four fuels during the series. One company used a slightly modified form of this schedule that, however, accomplishes the same result of eliminating so far as possible the effects of changes in weather and in individual characteristics of cars and drivers from the final averages, as was explained in the report made last winter.

Figs. 2 and 3 illustrate the arrangement of the forms used for the tabulation of data in the summer tests; the data sheets for the winter tests were substantially the same, with the exception of fuel and car designations.

Companies Making Tests

The ten companies listed below cooperated in the tests. The results from one company have not yet been received by the Research Department, and those from one other firm were not obtained nearly enough in conformity with the generally adopted and recommended procedure to warrant their inclusion in the report.

Autocar Co.
Buick Motor Co.
Dodge Bros., Inc.
Ford Motor Co.
Hupp Motor Car Corporation.
International Harvester Co.
Packard Motor Car Co.
Stromberg Motor Devices Co.
Studebaker Corporation of America.
Waukesha Motor Co.

Results

The mileages covered by the different cars during each week of the test were distributed as shown in Table 1, the greatest number of car-week mileages ranging between 100 and 199. The total mileage, 50,136, was obtained from 226 test periods. The shortest run was 39.8 miles, the longest 1,014.0 and the average 222.0.

TABLE 1—MILEAGE DISTRIBUTION IN TEST RUNS

Distance, Miles	Number of Runs
39-99	30
100-199	108
200-299	40
300-399	20
400-499	13
500-599	10
600-699	2
700-799	1
800-899	1
1000-1014	1

Table 2 gives the miles and ton-miles per gallon for each of the cars for each of the four fuels. The group averages are indicated, and the grand average for each fuel is to be found at the bottom of the proper column.

TABLE 2—MILEAGE AND TON-MILEAGE PER GALLON OF GASOLINE

Fuels / Car No.	Miles per Gallon of Gasoline □	×	○	△	Carbureter Adjustments Made	Ton-Miles per Gallon of Gasoline (Load of 300 lb. for passengers assumed) □	×	○	△
1	11.1	12.4	14.5	....	?	18.3	20.5	23.9	....
2	12.9	10.7	11.2	12.8	?	21.3	17.7	18.5	21.2
3	16.4	13.6	13.5	14.9	?	27.0	22.4	22.2	24.6
4	12.4	13.8	11.6	11.4	?	20.4	22.8	19.1	18.8
Average	13.2	12.6	12.7	13.0		21.8	20.9	20.9	21.5
5	13.8	8.4	15.5	14.2	?	26.9	16.4	30.2	27.7
6	11.3	12.6	11.9	11.1	?	18.6	20.8	19.6	18.3
7	11.4	12.0	12.3	11.9	?	18.8	19.8	20.3	19.6
8	10.8	....	....	10.9	?	17.8	....	....	18.0
Average	11.9	11.0	13.2	12.2		20.5	19.0	23.4	20.9
9	11.7	10.1	6.6	10.4	Yes	17.7	16.7	11.0	17.2
10	11.1	11.4	11.9	12.4	Yes	18.3	18.8	19.6	20.5
11	11.9	10.1	11.9	10.4	Yes	19.6	16.7	19.6	17.2
12	10.1	10.9	9.9	14.4	Yes	16.7	18.0	16.4	23.8
Average	11.2	10.6	10.1	11.9		18.1	17.6	16.7	19.7
13	11.8	10.6	9.2	12.5	Yes	19.5	17.5	15.2	20.6
14	6.9	7.8	8.0	8.5	Yes	11.4	12.9	13.2	14.0
15	13.3	10.6	10.0	13.4	Yes	22.0	17.5	16.5	22.1
16	14.1	9.4	11.8	10.0	Yes	25.4	16.9	21.2	18.0
Average	11.5	9.6	9.7	11.1		19.6	16.2	16.5	18.7
17	10.0	12.1	9.3	13.2	Yes	16.5	20.0	15.3	21.8
18	7.8	15.4	7.5	8.9	Yes	12.9	25.4	12.4	14.7
19	9.9	10.5	11.0	11.2	Yes	16.3	17.3	18.2	18.5
20	11.4	8.0	9.0	10.2	Yes	18.8	13.2	14.8	16.8
Average	9.8	11.5	9.2	10.9		16.1	19.0	15.2	17.9
21	18.5	13.1	17.7	15.1	Yes	30.3	21.6	29.2	24.9
22	15.0	15.8	20.5	16.2	Yes	24.8	26.1	33.8	26.7
23	10.9	12.7	14.0	18.7	Yes	18.0	21.0	23.1	30.9
24	19.9	15.7	12.9	10.4	Yes	32.8	25.9	21.3	17.2
25	15.9	14.8	18.9	12.0	Yes	26.2	24.4	31.2	19.8
26	13.2	13.9	12.1	10.2	Yes	18.5	19.5	16.9	14.3
Average	15.6	14.3	16.0	13.8		25.1	23.1	25.9	22.3
27	15.5	14.0	12.4	13.7	Yes	22.4	20.3	18.0	19.9
28	14.0	13.4	11.5	12.5	Yes	20.3	19.4	16.7	18.1
29	12.8	13.0	13.1	13.4	Yes	18.6	18.9	19.0	19.4
30	12.6	12.3	12.6	14.4	Yes	18.3	17.8	18.3	20.9
Average	13.7	13.2	12.4	13.5		19.9	19.1	18.0	19.6
31	13.8	13.6	13.3	13.3	No	22.8	22.4	22.0	22.0
32	15.5	15.1	14.5	16.2	No	25.6	24.9	23.9	26.8
33	15.5	15.5	14.7	14.3	No	25.6	25.6	24.2	23.6
34	10.2	9.2	9.0	8.0	No	24.0	21.6	21.2	18.8
35	13.5	15.2	14.6	15.3	No	22.3	25.1	24.1	25.2
36 (*a*)	11.5	10.7	11.1	11.4	No	....	....	....	....
Average	13.8	13.4	12.9	12.9		24.5	23.6	22.8	22.8
37	11.0	12.9	12.0	11.3	Yes	18.1	21.3	19.8	18.6
38	14.7	15.4	16.5	13.2	Yes	19.8	20.8	22.3	17.8
39	17.6	19.2	13.4	15.6	Yes	25.6	27.8	19.4	22.6
40	11.0	16.6	9.9	10.7	Yes	16.5	24.9	14.8	16.0
41 (*b*)	11.4	13.5	12.4	13.5	Yes	17.7	20.9	19.2	21.0
Average	12.8	16.1	13.0	13.1		20.1	23.7	19.6	19.4
42	13.8	14.2	15.6	13.8	Yes	24.2	24.9	27.3	24.2
43	11.0	10.4	9.9	9.8	Yes	19.3	18.2	17.3	17.2
44	11.6	11.8	9.8	10.9	Yes	20.3	20.6	17.1	19.1
45	10.9	10.6	9.7	9.7	Yes	19.1	18.6	17.0	17.0
Average	11.8	11.7	11.3	10.8		20.7	20.6	19.7	19.4
46	12.4	12.9	8.0	9.7	Yes	20.4	21.3	13.2	16.0
47	9.7	9.8	7.6	10.6	Yes	16.0	16.2	12.5	17.5
48	11.7	11.4	10.9	11.1	Yes	19.3	18.8	18.0	18.3
49	11.1	9.6	9.9	12.1	Yes	18.3	15.6	16.3	20.0
Average	11.2	10.9	9.1	10.9		18.5	18.0	15.0	17.9
50	19.9	19.7	18.8	14.3	Yes	27.8	27.6	26.3	20.0
51	16.8	15.8	14.5	12.9	Yes	23.5	22.1	20.3	18.1
52	17.4	15.2	16.2	15.6	Yes	24.4	21.3	22.7	21.8
53	17.5	18.3	16.5	17.2	Yes	24.5	25.6	23.1	24.1
Average	17.9	17.3	16.5	15.0		25.1	24.2	23.1	21.0
54	10.6	8.9	17.4	6.7	?	9.5	8.0	15.7	6.0
55	10.0	9.6	9.7	11.7	?	11.0	10.6	10.7	12.9
56	11.7	15.6	12.1	13.7	?	12.9	17.2	13.3	15.1
57	10.0	12.4	14.0	12.1	?	9.0	11.2	12.6	10.9
Average	10.6	11.6	13.3	11.1		10.6	11.8	13.1	11.2
Grand Average	12.8	12.7	12.4	12.4		20.2	19.9	19.4	19.5
90 per cent point, deg fahr.	362	375	420	430		362	375	420	430
Average Temperature deg. fahr. 50 per cent to 97 per cent on Distillation Curve	315	328	380	378		315	328	380	378
Grand Average Miles per Gallon and Ton-Miles per Gallon	12.8	12.7	12.4	12.4		20.2	19.9	19.4	19.5

(*a*) Special car.

(*b*) Values combined with those of another car to form group of four for average.

From the grand averages it is noted that the fuels fall into two groups, □ and ×, and ○ and △, according to mileage and less definitely so for ton-mileage. The grand average for miles per gallon on □ and × fuels exceeds that for ○ and △, the less volatile pair, by approximately 2.8 per cent. In ton-mileage, the excess of the more-volatile over the less-volatile pair amounts to approximately 3.1 per cent.

The agreement as to grouping and relative position between volatilities and both mileage and ton-mileage pairs is of interest. The agreement also holds for the values of average volatility between the 50-per cent and 97-per cent points of the distillation curves as can be seen by referring to bottom of Table 2 and to Fig. 1.

While the differences in grand averages of mileage and ton-mileage are not very great for the different fuels, yet the remarkable consistency between these averages and the fuel volatilities as shown at the bottom of Table 2 presents substantial evidence that the average fuel-consumption increases with decreasing volatility under winter conditions.

This conclusion is drawn in spite of the fact that the individual group averages are not in all cases in accord with the grand averages. This is to be expected, considering the fact that some of the tests were run without any readjustment of the carbureter, since under this condition the decreased volatility of the fuel, as shown by the summer tests of the Bureau of Standards, increases the mileage at the expense of performance, the higher viscosity of the less volatile fuels increasing the air-fuel ratio.

A comparison between the results of the summer and the winter fuel-tests is given in Table 3. In this the group averages for cars of a given make and model run in the summer tests are compared with group averages of the same or similar cars of the same make and model in the winter tests. For simplicity the winter averages are given for the two pairs of fuels, while the summer averages are given by only one value for the four fuels. It will be recalled that the summer tests brought out

TABLE 3—COMPARISON BETWEEN SUMMER AND WINTER RESULTS OF MILES PER GALLON

Car No.	Average Miles Per Gallon □ and × Winter	○ and △ Winter	A, B, C, D Summer
10, 20	10.5	10.9	14.7
9, 18	11.3	8.4	13.8
21, 26	14.9	14.9	16.2
27-30	13.5	12.9	16.6
31-33	14.8	14.4	15.4
42-45	11.8	11.1	13.5
46-49	11.1	10.0	13.0
50-53	17.6	15.8	17.3
Average of Above Values	13.2	12.3	15.1
Grand Average of All Values	12.7	12.4	14.8

TABLE 3. AVERAGE TEMPERATURES IN DEGREES FAHRENHEIT

Date	Weekly Average Lowest	Weekly Average Highest	Average for All Tests
1-8	26	42	32
9-15	29	45	35
16-22	30	44	37
23-29	31	44	37
30-Feb. 5	36	47	40

[illegible] difference in miles per gallon for the four fuels.

A consistent and important decrease in mileage for the winter tests over the summer tests is apparent, the greatest difference amounting to approximately 18 per cent between the grand averages. It should be emphasized that these averages are for cars of the same model and in a majority of instances they are the same cars in the hands of the same drivers; hence the 18-per cent increase in fuel consumption may be taken as fairly representative of what is to be expected in average service.

The average temperatures during the tests on several of the cars are given in Table 4.

Carbureter Adjustment

The reports of three of the companies made no reference to carbureter setting; it is assumed that no special adjustments were made. One of the companies stated that the tests on its group of cars were run with fixed settings. Four of the companies reported the adjustment of carbureters for the best operation with the fuel in use.

The method used by one of the four was to have the same person make all settings with the object of obtaining maximum power; the basis was to require that the car accelerate from 15 m.p.h., with water temperature at 120 deg. without backfire. One company found it necessary to make a new adjustment for each grade of fuel to obtain the same idling and acceleration performance on the road. A third company adjusted for the best fuel-economy. A fourth company had all carbureters adjusted by the same engineer to have the mixture sufficiently rich so that after running a distance of six city blocks the car would accelerate from 5 m.p.h. without missing or hesitating.

Comments of Drivers

Drivers from seven of the companies submitted comments characterizing the fuels with regard to their general driving qualities. The statements of reports naming the fuels in the order of preference have been assembled in Table 5 and are summarized below.

In 10 of the 13 reports on the order of choice first place was definitely assigned to × fuel, while one was undecided between × and Δ; □ was mentioned in two cases. Thus, × fuel appeared for first place in 11 of the 13 reports. For second choice seven of 13 reports definitely assigned second place to Δ fuel, while one was undecided between Δ and ×; □ was mentioned in three cases; and × in two. Thus, Δ fuel figured as second choice in eight of the 13 reports. Four of the 12 reports definitely assigned third place to □ fuel, while three were undecided between □ and O; Δ was mentioned in two cases, and O in one; Δ and O were tied for third place in two reports. Thus, □ fuel appeared in seven of the 12 reports. For fourth choice seven of the 13 reports definitely assigned fourth place to O fuel, three were undecided between O and □, and two between O and Δ; □ was mentioned in one report. Thus, O appeared for fourth choice in 12 of the 13 reports.

In attempting then, to summarize the drivers' order of preference as based on the general driving merits of the fuels, it seems reasonable to assign first, second, third, and fourth place to ×, Δ, □, and O fuels in the order named. It is seen that the two extremes are very definitely decided, while the intermediate choices are more scattered.

Several of the drivers gave more specific opinions as to the starting, acceleration and power characteristics. These, in general, indicate agreement with the order of preference above stated. Extracts from several reports are given below in Table 6.

Referring to the distillation curve shown in Fig. 1, it is interesting to note that the order of preference follows the order of volatilities from the 14-per cent point to the 20-per cent point of the curves. This range appears to determine the starting and acceleration characteristics. The order of preference is largely determined by starting characteristics, and relatively small differences in volatility in this range have a marked effect.

TABLE 5. DRIVERS' COMMENTS BASED UPON OBSERVATIONS OF DRIVING CHARACTERISTICS

Fuel	Second	Third	Fourth
×	□	Δ or O	O or Δ
× (a)	□ (a)	Δ (a)	O (a)
× (d)	□ (d)	Δ (d)	O (d)
× (d)	□ (d)	Δ (d)	O (d)
× (d)	□ (d)	Δ (d)	O (d)
× (d)	□ (d)	Δ (d)	O (d)
× (d)	□ (d)	Δ (d)	O (d)
× (e)	Δ (e)	□ (e)	O (e)
× (a)	× or □ (a)	Δ or O (a)	O or □ (a)
× (a)	Δ (a)	Δ or O (a)	O or □ (a)
× (e)	□ (e)	Δ or O (e)	O or □ (e)
× (a)	□ (a)	O (a)	Δ (a)
× (a)	□ (a)	Δ or O (a)	O or □ (a)

Crankcase-Oil Dilution

Samples of the new and used oils were sent to the Bureau of Standards for test. The results of these tests, so far as completed to date, covering 22 of the cars are shown in Table 7 arranged according to groups and car numbers.

As in the summer tests, the dilution is found to increase in general as the volatilities decrease. The O and Δ fuels are substantially the same. These two fuels have the same 80-per cent point on the distillation curve and the relative volatilities reverse at this point. Furthermore, it is to be noted that □ and × and O and Δ, are grouped roughly in pairs and that the dilution for the less-volatile pair, O and Δ, exceeds that for the more-volatile pair, □ and ×, by approximately 43 per cent.

The Saybolt viscosities of the samples of used oil are also given in Table 7. The grand averages run 125, 115, 82, and 81 sec. for fuels □, ×, O, and Δ, respectively.

Conclusions

Twelve of the larger companies, in cooperation with the Research Department of the Society of Automotive Engineers, in carrying through the two series of fuel-consumption tests last summer and last winter, have accomplished a result that could scarcely have been secured in any other way, and have demonstrated the practicability of such joint action on problems that are of sufficient importance to the industry as a whole to warrant the expenditure of the very moderate amount of time and money involved by each of several companies.

The two series of tests, including observations covering nearly 500 car-weeks of driving under summer and

winter conditions, with the observations arranged to eliminate so far as possible the effects of weather and individual differences, afford a most reliable basis for conclusions as to the behavior of different fuels in the hands of the average driver.

So far as mileage alone is concerned, *under summer conditions* there is no important difference between the average mileages secured per gallon of fuel, as between the fuels tested.

Under winter conditions there is a small but definite increase in average fuel-consumption of about 30 per cent accompanying an increase of about 55 deg. in the 90-per cent point of the distillation curve. Taken by itself, this relatively small difference in mileage is unimportant

TABLE 6—EXTRACTS FROM DRIVERS' REMARKS

Car No.	□	×	O	△
1 to 8 inclusive			Practically unanimous complaint against these fuels.	
9	Excellent. Lots of pep and pull.	Same as ordinary commercial gasoline. Fairly good pull and pep.	Very poor. Hard starting. No pull or power.	Little better than O.
10	Difficult to start when cold but O. K. when hot.	Same as △.	Engine would not run smoothly until after 3 or 4 miles. Seemed to be adjusted for too lean a mixture.	Same as ×.
11	Best of four—Like ×. Best acceleration.	Better than △ considerably. No trouble in starting or running.	Like △. Same trouble in starting but not so much knock. No preignition.	Hard to start. Used hot water on manifold. Knock after warming. Preignition once.
12	More or less trouble. Needed to adjust carbureter using choke.	Trouble with starting. Slight knocks. No hot water needed in starting.	Better than ×. Practically no difficulty with this grade.	Satisfactory; little or no difficulty.
13	Only difference noted was that car was hard to start.			
14	Extremely cold weather and could not start without applying hot water.	No difficulty in starting. Ascribed to warmer weather.	Started much better than any other. After warm was as good as any gasoline.	Better than □ but not as good as should be in starting.
15	Same as O.	Same as △.	Great difficulty in starting.	Very little difference from regular gasoline.
16	Poorest action. Less mileage. Harder starting. Sluggish and little speed.	Performance in starting and running similar to commercial gasoline.	Much slower starting and less mileage. Plenty of power after heated.	Very much like ×.
17	Had no trouble and could detect no differences.			
18	Noticed no difference.	Not so much pick-up and power as with □ and ×.	Not so much pick-up and power as with □ and △.	Noticed no difference.
19	More trouble in starting. Tendency to back-fire after turning off ignition.			Good performance. No difference compared with previous operation.
20	Sometimes necessary to wait a minute or so before enough power to start. Poor pick-up.	Worked well, started easily, picked-up well.	Started well but did not pick-up rapidly.	Same remarks as ×.
21 to 26 inclusive		Best starting. Leanest carbureter setting.		Poorest starting. Richest carbureter setting.
27 to 30 inclusive			Drivers all complained of trouble in warming up and getting started.	
37 to 41 inclusive	Very satisfactory; almost as good as ×.	Very good for starting, warming-up and acceleration.	Extremely bad; most of drivers protested against using it.	Less satisfactory than gasoline ordinarily used, but better than O.
54	Good starting power when warm.		Hard starting; no power till warm.	Good starting and power.
55	Good starting.	Very easy starting.	Same as above.	Hard starting.
56	Hard to start; good power when warmed.	Easy starting; no acceleration till warm.	Fairly good starting.	Hard starting.
57	Good starting.	Hard starting.	Hard starting; no power till warmed.	Hard starting; poor running till warm.

compared with the estimated difference in the relative amounts of the two extreme grades of fuel from a given quantity of crude oil.

The results on crankcase-oil dilution are not complete, as only part of the samples have yet been tested. So far as they go, however, the tests show an increasing amount of dilution and a corresponding decrease in viscosity of the oil after use as the fuel volatility decreases.

The average of results at hand shows an increase of 44 per cent in the amount of dilution with fuels differing by 55 deg. at the 90-per cent distillation-point, and for the viscosities in Saybolt seconds at 100 deg. fahr., of 300 for the new oil and of 125, 115, 82, 81, the average viscosities at the end of a week's run, for each of the four test-fuels respectively.

Differences in starting and general performance as noted by the drivers correspond with the relative volatilities of the fuels in the range of 15 to 20 per cent of the distillation curve. The drivers chose the fuels having the highest and the lowest distillation-temperature in this range with remarkable consistency, notwithstanding the small differences that exist in this range.

TABLE 7—CRANKCASE-OIL DILUTION

CAR NUMBER	Fuels Used							
	□		×		○		△	
	Dilution Per Cent	Viscosity at 100 Deg. Fahr., Saybolt Sec.	Dilution Per Cent	Viscosity at 100 Deg. Fahr., Saybolt Sec.	Dilution Per Cent	Viscosity at 100 Deg. Fahr., Saybolt Sec.	Dilution Per Cent	Viscosity at 100 Deg. Fahr., Saybolt Sec.
New oil		300		300		300		300
9	20.8	90	22.0	77	22.3	65	28.5	65
10	12.5	129	18.5	97	27.7	69	31.5	66
11	14.0	123	15.8	108	21.5	85	21.5	90
12	21.5	79	12.0	90	33.6	59	15.7	122
Group 3 Average	17.2	105	14.1	93	26.3	70	24.3	86
13	19.5	92	35.0	55	13.8	82	27.0	47
14	10.5	127	14.2	125	20.8	89	20.0	92
15	28.0	176	23.0	87	13.0	128	14.0	129
16	15.0	112	17.0	102	25.5	78	9.0	66
Group 4 Average	18.3	127	22.3	92	18.3	94	17.5	84
17	18.0	95	17.5	97	17.5	103	22.8	83
18	9.0	149	19.8	93	29.0	64	22.8	78
19	13.3	130	12.6	120	19.3	98	21.5	90
20	24.0	70	29.0	63	42.0	47	36.5	53
Group 5 Average	16.1	111	19.7	93	27.0	78	25.9	76
21	5.5	140	6.3	159	11.4	111	16.5	78
22	7.8	141	7.6	149	14.8	104	15.5	95
23	8.1	140	7.5	154	12.3	104	20.5	82
24	12.5	128	9.9	138	23.6	73	24.8	69
25	7.2	156	7.7	149	23.0	75	22.4	78
26	9.4	134	8.6	137	18.9	90	22.7	74
Group 6 Average	8.4	140	7.9	148	17.3	93	20.4	79
27	11.0	165	9.5	199	22.0	83	26.3	79
28	11.2	132	20.0	95	48.6	44	27.7	71
29	14.0	112	14.5	107	29.0	66	32.0	63
30			13.5	120	22.5	75	9.7	104
Group 7 Average	12.1	136	14.4	130	30.5	67	23.9	79
Grand Average	13.9	125	15.5	115	23.3	82	22.2	81

Determinations of flash point by manufacturer; others obtained from Bureau of Standards tests of samples.

ANALYSES OF NEW OILS

Fuel in Use	Gravity		Flash Point, Deg. Fahr.	Fire Test, Deg. Fahr.	Viscosity at 100 Deg. Fahr., Saybolt Sec.
	Specific	Baumé			
Group 1, 2, 3	0.935	19.6	355	395	300
	0.935	19.6	345	400	301
Group 4	0.937				297
Group 5	0.932	20.2	355	420	306

The Factory Engineering-Staff and Its Relation to Service

By J. W. Lord[1] Metropolitan Section Paper

SERVICE problems, fundamental in character, that must be solved at the point where the vehicle is designed and produced are the only ones considered, and all of them involve the factory engineering-organization. The author states an existent feeling in the service field that the factory engineers are inclined to be arrogant and obstinate, almost invariably taking the attitude that a difficulty is likely to be due to anything except design, material or workmanship; but he believes this situation will disappear as the factory engineer takes more interest in service problems and comes more closely into contact with service and maintenance.

The problems due to inaccessibility of parts, repairs and repair parts are discussed, and the influence that the factory engineer has and can have on service are treated in some detail. A recommendation is made that engineers be given greater opportunity to see the product in the field.

THIS is a broad topic and, before giving thought to it directly, I believe it well to analyze briefly why service is being pushed so much into the foreground today, its place and value in the automotive industry and the problems it involves. The real reason service is becoming of such importance is that the public is demanding better, cheaper and more prompt repairs, and showing preference for those who will make them, just as it demanded greater reliability earlier in the history of the industry and, later, reliability at a lower first cost. The public realizes that the majority of cars of today are fairly reliable and that, so far as car value is concerned, one gets about what one pays for; but the public is also becoming educated to the automobile as a machine that wears, and it realizes more and more that maintenance has not received the close study that has been given the product from the performance and production angles. I believe the builder who can sell the most miles per dollar of reliable car or truck transportation is the one to whom the public will come with transporation problems. An honest, well-designed and well-built machine cannot fill this requisite by itself. It must be backed by facilities for prompt, honest, well-made repairs of the stitch-in-time variety and those of more extensive nature, that become necessary as the car mileage runs up.

We often hear an owner say that his car is a fine machine but that it costs a fortune to keep it running. Distributors are having this thrust at them every day and more than ever recognize that good service, better, cheaper and more prompt maintenance or service are prominent and powerful selling factors. The customers' purchase of transportation is not complete without them. This is the value of service and its place in the industry.

Henry Holt, former president of the Automotive Service Association, said that our whole aim in service work should be to sell more cars by making them fulfill the purpose for which they were made. The service-station must cooperate with the sales end of the organization to sell more cars; it must make the cars give the greatest of satisfaction, so that when people need new cars they will come back and get them.

There are many problems of service, one class of which require local solution and do not directly involve the factory, but there are service problems, fundamental in character, which must be solved at the point where the vehicles are designed and produced. It is only this latter class that need be considered in this paper, and all of these problems involve the factory engineering organization.

Service-stations must primarily do their utmost to keep the product on the road, whether this involves making the usual normal repairs or making emergency repairs necessary because of faulty design, workmanship or material. Repairs of this latter variety demand much of service, particularly when a truck is involved. The job must be put on the road again with all possible speed. It seems at times that the more successful a service-station is in making such repairs, the less attention is given by the factory to the real cause of the trouble. Sometimes such difficulties are allowed to gain great headway and, when the engineer finally does realize that a serious condition has arisen, which must be taken care of, it can only be done at most heavy expense. That such things can and do happen and can continue, is difficult to explain. Perhaps many an engineer feels that the average service-station loudly cries "wolf" whenever any difficulty, no matter how trivial, first appears. On the other hand, there is a feeling in the field that the engineers at the factories are inclined to be arrogant and obstinate; almost invariably taking the attitude that a difficulty is due to anything except design, material or workmanship. I believe this situation will disappear as the factory engineer takes more interest in service problems and comes much more closely into contact with service and maintenance.

Accessibility and Repairs

The problem of accessibility in making repairs deserves the attention and the continuous study of the factory engineers. To customers and their chauffeurs some repair jobs seem to take an unnecessarily long time, often due to the job being within easy vision but most inaccessible. The service-station may convince the owner that under the circumstances, the time was reasonable; but when the bill has been paid, the owner feels he has paid more than necessary for a simple repair and, fundamentally, he is right. This matter has been well presented by B. M. Ikert and others and I need not enlarge on it. I only repeat, accessibility is a maintenance problem to be handled at the point of production.

The matter of selling repairs also deserves the attention and the study of the factory engineers. I believe flat-rate service to be the most satisfactory method of selling maintenance, and that it will become general. The rate should cover the finished job, both labor and material. A flat labor-rate only sets up a situation that places a premium on using new parts, rather than ex-

[1] M.S.A.E.—Service manager, Harrolds Motor Car Co., New York City.

where some small part of a comparatively large unit is worn or broken. Provision should be made to take care of the wear without replacing the entire expensive part. The factory engineer is in position to do much to improve these parts problems. The foregoing briefly outlines some of the service problems to be solved at the factory.

The Factory Engineer's Influence

So far as the factory engineer is concerned, it seems to me that the industry has gone through two distinct engineering phases and is entering a third. I call them engineering phases because I believe that the further development of the industry lies in the hands of its engineers. The first phase was to design an automobile that would run, that would perform. The second was a further development of the first, coupled with design to facilitate production. The third was a further development of the first two, coupled with design to facilitate maintenance.

It is only natural and to be expected that the factory designing-engineer is fully in accord with design from a production viewpoint as well as that of performance. Production interests are right at hand. The production engineer is always at his elbow, continually showing him how a slight alteration of the design will not affect the performance but will simplify production and reduce costs. By virtue of this continual contact, the designing engineer becomes somewhat a production engineer himself. On the other hand, maintenance and repair have been far afield. They have not been physically close to the engineer. They have been brought to his attention by cold, indifferent reports that normally do not make the vivid impressions that come from first-hand contact, a contact that can be obtained only by traveling and spending time right in the service-stations and in close contact with the repair work just as it comes in.

Some companies have developed an engineering group in their service departments. Such a group can follow closely the performance of the company's product in the hands of its customers. From various sources of information, such as roadmen's reports and letters, distributors' reports and letters, parts returned claimed defective and parts orders, they can gather statistics giving an index of what is happening and, by periodical reports, can inform the management and the engineering and the manufacturing departments of what they find. It is possible for them to go much further and develop tools and repair methods and collect various data regarding repairs to older models that today each individual distributor's service-station is working out for itself at great expense. I believe all this is good organization, and a step in the right direction. Such a group is constituted of the logical ones to work with the chief engineer on matters of accessibility and on design to facilitate rapid repair, to insure the use of standard tools and the like, but its members will not work in the closest of harmony with the designing engineer until he gets away, sees maintenance and service as actually rendered to the public and realizes the vast possibilities for improvement that the dominant position he holds makes it possible for him to initiate, and until it is his intense desire to develop this phase of the industry.

I believe the designing engineer needs this intimate contact with service and that the factory management which will see to it that its engineers get this intimate contact with maintenance will be amply rewarded by a product that will give less trouble in the hands of its owners and one that can be maintained at less expense.

Such a product is bound to reflect itself in a reduced policy-account of charges absorbed for making-good on defects developing in the field.

I think that there is a tendency to hold the designing engineer much too closely to getting out the department drawings, so that he becomes not much more than a chief draftsman. I suggest an organization involving an assistant executive-engineer who can push the department work along, giving the chief time to get away and secure first-hand knowledge of maintenance or repairs and of service-station problems. I fully believe that with this intimate contact will come a knowledge and realization of service almost unknown today, which will be so real and so much a part of the engineer that his work in design will reflect it to the benefit of the industry, just as his intimate contact with production led to the rapid development of the industry. It seems to me that this will never happen until the engineer is as familiar and in as close contact with the problems of service as he is with those of production. For the good of the industry, its engineers should take more opportunity and be given more opportunity to see the product in the field.

L. J. Eastman remarked that the service man is a sort of younger brother. That is a very fine way of putting it and, speaking as a younger brother, I say that we want our older brothers to get much closer to our problems. They will help us and, we believe, in doing that, they will help themselves and the industry as well.

THE DISCUSSION

B. B. BACHMAN:—Probably no one is more thoroughly in sympathy with the idea of service and what it means to the industry than I am. I have fortunately been associated with an organization that has attempted to build the foundations of its business upon a satisfactory service organization and a complete service plan. We have had some opportunities of doing things, in the type of organization which we have used, that not everyone can follow who does not have the same type of industrial organization. The fact that a very large percentage of our product is marketed through our own branches places the engineering department in a very much closer contact with the people who are selling and servicing the product than I can conceive possible with a distributor organization involving multitudes of independent individuals.

C. B. VEAL:—The problem resolves itself almost entirely into one of management; it is not a difference of opinion between the engineers and the service-men themselves.

J. G. VINCENT:—I think Mr. Bachman is absolutely right when he states that one of the biggest values of the flat-rate system of service charges lies in the necessity for carefully analyzing service operations from a cost viewpoint. To this I would add a corollary to the effect that such analysis in any line of business almost invariably results in a great gain in efficiency which, in this particular case, means a lower cost of service to the vehicle owner.

I am inclined to doubt that the averaging of costs over the car that is taken care of and the car that is neglected is any worse from the owner's viewpoint than the fact that, on a time-and-material basis, the vehicle owner lucky enough to draw the fastest men in the service-station has an advantage over those less fortunate. In addition, the man that takes care of his vehicle will not be in for the work as often as the man who neglects his vehicle. As a matter of fact, the vehicle is designed in the first place on the basis of averages, plus the proper factor of safety. By this I mean that the vehicle is designed as nearly as possible to give good all-round results whether operated in the country or in the city, in the North or in the South, in the mountains or on the plains, by the hard driver or the easy one, all of which means that every owner sacrifices a little so that other owners with other operating conditions can get satisfactory results also. Obviously, if the vehicle were designed to fit only one set of conditions, somewhat better efficiency could be expected under those particular conditions; and the reverse would be true under other conditions unless several types of the same vehicle were produced. As I see it, the flat-price system of servicing handles costs along the same lines, that is, on broad general averages, is perfectly fair therefore, and not only is a more businesslike method of doing business, but also one that promotes efficiency throughout the relations between the service-station and the vehicle owner.

As I see it, Mr. Lord has covered the subject in excellent style; in fact, our procedure at the Packard Company has been very much along the lines Mr. Lord advocates. As an example of this, approximately 5 years ago we organized a separate division in our engineering department to handle service field-problems from an engineering viewpoint, and it is to service field-suggestions, properly analyzed and checked, that many of our current-model refinements have been due. Naturally, this department has been very close to the laying-down of new vehicles, to avoid the possibility of repeating previous service field-conditions. It is true that a great many service-field suggestions do not successfully stand investigation; this Mr. Lord refers to on the basis that the service-station may frequently cry "wolf." On the other hand, those that are substantiated more than offset the time lost on the other variety.

Along the same lines, the matter of accessibility of parts and units has been given very careful consideration, and a very definite advance has been made, largely as a result of our contact with the service field. Our technical service-department that handles the business negotiations with the service field tells me that the flat-rate system of service charges is now in effect in our service-stations and has given an excellent account of itself. In addition, it is stated by that department that the system has been improved recently by making the flat rate uniform throughout the Country according to three zones, and this appears to me to be very logical. In that same department service or repair tools are being developed from suggestions made by the factory organization, or from the service field and made available to the latter, and equal attention is being given to the proper ratio of vehicles to the quantity of service stock, so that each service station can carry the proper amount. In addition, the actual retail prices of the service parts are continually being scrutinized to keep them fair and proper. Naturally, the engineering department is assisting the technical service-department continually in all of these matters, and there is no question that the procedure is more than warranted.

A. J. SCAIFE:—The most important person to be considered is the customer, and any method that will bring the customer's viewpoint and his difficulties to the attention of the engineering staff should receive very careful consideration. It is undoubtedly true that every automobile plant of any consequence has a very elaborate method of tabulating complaints and recording parts failures in service, but it is difficult to get a large engineering organization stirred-up to the necessity of giving these complaints the consideration they should re-

Mr. Lord. This information is brought into the factory, the individual making his report in person to the engineering committee. In this way, the most serious complaints are acted upon very quickly, and the other complaints receive consideration in proportion to their importance. This accomplishes two things; it brings the customer's viewpoint directly to the attention of the engineering staff and, in turn, it brings the engineering department of the factory directly into contact with the customer. The owner has many things to bring to the attention of the engineer, and the engineer also has many things to bring to the attention of the owner.

O. E. HUNT:—We thoroughly agree with Mr. Lord that the average factory engineering-organization is not closely enough in touch with the service problem and, as a result, has not the right attitude of mind toward it. We feel, however, that this condition is rapidly changing. The present highly competitive state of the industry has compelled all companies to appreciate that they are selling transportation service rather than a collection of design features, and that they will succeed just in proportion as they convince their public that they are giving comfortable and dependable transportation at less cost per mile than their competitors. This means that they cannot consider that the job is fully engineered until it has worn itself out in satisfactory service. This will certainly result in the service-man's getting more help from the factory organization than he was ever able to get heretofore. Economic pressure is sure to force the factory organization to help him.

R. E. FIELDER:—Service or maintenance of automotive equipment is a vital matter, particularly to the public-service corporations and other large companies rendering a definite daily service to the public at large.

A typical case might be described by taking the newest form of automotive service, that of mass transportation of passengers by motorbuses. In most cases a number of vehicles are used and are operating frequently for upward of 18 hr. per day, 365 days in the year. When using these vehicles, the public will insist that it arrive at its destination without any undue delay such as might be incurred by an involuntary stop due to a deficiency of mechanical maintenance. This state of affairs will necessitate that the operating company employ several experienced mechanics, and the time of work for these mechanics must be divided so that they cover the whole period of bus operation. It is obvious that, with this class of service, it will never be profitable to go to an independent garage or service-station at any time of the day or night and expect to get immediate attention for any bus while in service. If this were resorted to, there undoubtedly would be a tremendous loss of revenue due to buses lying idle or awaiting the convenience of another company to get them into operating condition.

In regard to the relations between operating and designing engineers, it is understandable that the designing engineer will ignore the experience and reports of his brother operating engineer since, primarily, vehicles are produced to render a transportation service and the efficiency of that service depends mainly upon the convenience to the user, as compared to cost of manufacturing. The fundamental vehicle-requirements of the operating engineer are accessibility, simplicity, independent unit-construction, light-weight units that are easily handled, elimination of surplus refinements, fool-proof and accessible adjustments and lubrication devices that are accessible and have adequate storage capacity.

The ever-growing use of large fleets of automobiles operated under the control of individual companies has made it comparatively easy for the designers and the builders of the equipment operated to gain an easy and first-hand knowledge of the efficiency of their designs for the purpose for which they are used. The following is a system that has been successfully used:

(1) Every vehicle should be supplied daily with a card prepared so that the driver can write thereon all the faults and defects with which he has had experience during that day in the operation of his vehicle; also the mileage operated, the fuel and the oil consumed

(2) An experienced mechanical inspector should be allocated to the garage to receive the card from the driver of the vehicle, make an inspection of said vehicle in the presence of the driver and check his reports according to the cards

(3) Assuming the operation of a large number of vehicles, say 50 or more, the adjustment and repair work of those vehicles will be divided then among mechanics who are specializing in certain portions of the chassis, such as brakes, rear axles, change-speed and transmission gears, engines, gasoline tanks, and ignition and carburetion apparatus. Each of these various mechanics will have given to him a sheet on which will be marked the vehicle numbers that need attention with respect to the particular device in which he is specializing. Therefore, the information checked by the inspector from the driver's card will be transferred to the mechanic's sheet so that he can make the necessary adjustments and repairs during the interval that the vehicle is in the garage. The mechanic making the repairs will be responsible also for recording the correct information regarding the adjustment he makes or defect that he finds

(4) The mechanic's sheets, after being used by him, will be turned-in to the main office, where the reports from his sheets will be transferred to a master record-sheet of the particular vehicle. This record sheet may be known as the general-inspection sheet, the general inspection occurring approximately every 2000 miles, and will serve as a guide for the mechanics in charge of the overhauling of this vehicle, informing them of the particular defects and weaknesses that have occurred during its past 2000 miles of operation. This inspection sheet also should contain data pertaining to the miles the vehicle has operated and the amount of gasoline and oil consumed

(5) This overhaul sheet, having been completed by the mechanics or others in charge of repair and maintenance, will be sent to the engineering department, where an analysis can be made of the difficulties that occur during operation. The defects that predominate will point out to the engineers the weakness of the particular parts giving trouble, affording them an opportunity to redesign and improve such parts and thereby forming that necessary link between the operating department and the designing department

Concerning the relations between operating and production engineers, it is apparent that most of the requirements for operating engineers have been transmitted, heretofore, to the engineering department by the salesman who, more often than not, is nothing more than a pleasant fellow, with little practical knowledge of either

his customer's operation requirements or the necessities of design. On the other hand, we have the expert production-engineer who cares little or nothing about operating efficiency so long as he can produce an article for a certain price. This combination, no doubt, has worked out fairly well in the past, particularly for the individual passenger-car operator whose use of an automotive vehicle is frequently confined to summer evenings and week-end parties.

The automotive vehicle is today coming into its own and it seems safe to say that in the next few years it will be used in enormous quantities by large companies. If we stop to consider that a vehicle operating for upward of 50,000 miles per year can save 1 cent per mile in its mechanical maintenance, its fuel consumption and its wear-and-tear on tires, we will realize that this saving of $500 will offset very easily the saving in the manufacturing department of a few dollars, affecting only the initial cost of probably a $3,500 chassis. Assuming the average life of this vehicle to be 6 years, according to the foregoing calculation $3,000 can be saved, or practically the cost of the chassis.

I believe that the time has come when the operating engineer is the one to say which is the best type of vehicle to purchase, and this will be decided entirely upon operating and not initial cost; hence, the operating engineer's influence on the design of certain types of vehicle will be great.

With reference to efficiency in operating departments, one other matter that needs very careful attention by the designers of automotive equipment is that of supplying the maintenance department with adequate tools and facilities for the removal or the repair of these vehicles. This is imperative. Also, it is imperative that the operating engineer have such tools and equipment efficiently cared for.

J. W. LORD:—It seems to me that many of the engineers, though interested in service, have not been given the opportunity to get as close to it as they should be, and that the responsibility for this condition lies perhaps more with management than with the engineers. Though written reports carry definite information to an engineer, actual contact carries a much more vivid and lasting impression; therefore, steps should be taken to secure such vivid impression. A written statement that, in the course of an engineer's many duties, "goes in one eye and out the other," has been proved to be of no great value. If the management would realize this and also the value of having its engineers come into contact with the product in the field, I am sure it would see the value of providing ways and means and establishing a routine so that both the designing and the production engineers would have an opportunity to get much closer to service than is the general rule of the day.

E. W. SEAHOLM:—In my opinion, there is no more important engineering problem or one that deserves more attention from the designing engineer than the improvement of the product in relation to service. The points brought out in Mr. Lord's paper are well taken and admirably stated. In our organization we have followed the method outlined for several years. We are continually striving to reach the ultimate of perfection. Our technical department, which is the engineering branch of our service, maintains a very intimate touch with conditions of service by direct contact and through road-men. All repairs, complaints and reports of parts replaced pass over the chief engineer's desk, and the tabulated data dealing with service problems serve as a valuable compass to our designers.

H. P. CROUZE:—I am glad to see that the engineers of the factory are beginning to feel that we service-men, who do all the squabbling with the owners, amount to something, after all. A number of them have asked us about some of our problems; strange to say, in the last 2 years they have listened to us.

W. J. DRETKE:—I am in accord with both Mr. Lord and Mr. Bachman. We have a field organization of seven service inspectors who visit plants manufacturing automobiles, trucks, tractors and other appliances in which our roller bearings are used. These field men bring to us all of the manufacturers' troubles. When necessary, they visit service-stations and bring their troubles in the field directly to the engineering and the service departments.

J. W. FLORIDA:—I attended recently one of the quarterly service meetings at our factory in Detroit. These meetings are held for the express purpose of bringing our service and maintenance problems before our engineers, who take the keenest interest in everything brought up. Those in attendance at these meetings comprise service managers of the various Packard distributors and dealers throughout the Country and factory officials and executives, as well as the factory field-men. With such splendid and progressive cooperation between the various district service-departments and the factory engineering-department, our service problems are kept at a minimum and service as a whole is held at a very high point of efficiency, thus effecting low maintenance costs to car-owners.

In regard to the so-called flat-price system, we call it standard-price repair-method and have adopted it nationally. We gave this system much careful thought and study to make sure of eliminating the "danger spots" that can easily enter it; these, we know, have been the cause of much unfavorable and just criticism against the flat-price system. With the aid of all its Class-A service-points throughout the Country, our factory was able to get a very broad view of what each repair operation costs and what the best methods are for doing them; so, after studying some 500 operations and striking an average of 10 similar operations from the various Class-A service-stations, some very gratifying results in getting prices to a lower level were obtained. Today, our standard-price repair-method is used by all our distributors and dealers. The system has for its main object the keeping of our customers' maintenance costs as low as possible consistent with the mileage and care their cars receive. In New York City, for instance, we have a higher labor cost than in many other sections where labor can be secured at cheaper rates, and it appears that in New York City we could not meet the low standard prices; but we have experienced no difficulty, because our volume of business and our facilities offset the handicap of the higher labor scale. I believe that the standard-price system has come to stay, especially when automobile companies go into it as thoroughly as ours has done and avoid the danger spots that existed in former so-called flat-price systems. Our standard-price system goes a long way toward helping our customers to keep their maintenance costs low.

L. T. HANFORD:—As a service-man, I will say that the subjects discussed indicate that, as engineers and service-men, we are on common ground in many ways. Certainly we both owe our jobs and livelihood to the car-owners, and we can pay our obligation to them by building and servicing the cars they buy and use in such a manner that the maintenance cost will be at a minimum to them. Personal contact will smooth out many of our

misunderstandings just as we service-men find it does with our customers. Service-men should visit their factories regularly, armed with constructive criticism born of experience in making service repairs and inspections. Likewise, factory engineers, or their assistants, should go out into the field regularly and visit the service-men, to learn just what they are up against and see specimens of the repair jobs that they have to perform. We sometimes wonder whether, in design and production, the engineers give any thought to the servicing of the units or the parts employed.

DAVID BEECROFT:—With regard to the flat-rate system, there is considerable very good psychology connected with its use. I had a very good example of that several years ago, in Milwaukee, showing the good spirit and better understanding that it created among the dealers there. The Overland organization started the flat-rate system about 2½ years ago in that city. The Nash organization in Milwaukee was not on the best of terms with the Willys-Overland Co., but they got together and talked over the flat-rate system, and a much better understanding developed between those organizations as a direct result. As an example of how it worked out, when the Nash organization took a Willys-Overland car in exchange, or vice versa, instead of attempting to do the repairing or overhauling in its own organization, it immediately passed the job over to the other company. The service managers of both organizations, and the managers also, admitted that, previous to the study they had given to this matter, they really did not trust each other to the extent of exchanging their overhauling work.

I think the effective psychology in the flat-rate system is that it puts both parties with their feet under the same table before the job starts; it means getting an understanding, presenting an analysis and, so far as the public is concerned, I think that is what it requires. The plan gets the public interested keenly in this matter when it sees the bills. The problem can be solved if it is analyzed at the start. The public is fully as willing to see the justice of the situation as the service department is to show the justice of it. If for no other reason than the fact that both parties get together and see the problem from perhaps a broader viewpoint, it is something that is very much to be desired. It is a confidence-building method.

RALPH ROGNON:—I believe we can obtain much benefit from this meeting. I believe an engineer lays plans and a service manager plans excuses; perhaps, regarding the latter, because we have not laid plans in the development of service. From the standpoint of the industry, we have simply been an adjusting department of the sales organization, in an industry that has had a quick growth.

There are two kinds of service; one is a warranty service and the other a maintenance service. When we lay definite plans and develop a maintenance service, we can take the axe, because we will not need to plan so many excuses. In analyzing the subject, there are three viewpoints. The first one is that of the owner. If we have a quota of 30,000 cars and the owners are paying a price for those cars without any consideration of a sane program of maintenance, the service department is suffering in the following way. Compared with the engineer of a locomotive in the operation of a printing press, the press operator from the machine as a craftsman, the average motorist simply seeks efficiency as a convenience. Instead of maintaining his car, he uses it for a period until trouble begins and then trades it in for a new one. In no other line of industry is the turnover so rapid or frequent as it is in ours, and I think we are suffering as a result of it. If we could educate the owner into a sane program of maintenance, we would be doing a great good. Any other industry that has been successful has taken as its policy public need and demand.

Second, from a maintenance viewpoint, our own problems simmer right down to the production department. The engineer, after laying his plans, does not have to call several men together and tell them to build a truck without any definite plan; but in a service-station, we are called upon to send for a mechanic and say to him, "fix it." Third, I do not know just how to lay the proper plans, but I think much good can be done along the line of the standardization plans of the Society. What would we do if we did not have standardized bolts and nuts, and all the various standards the Society has established? In service, we must outline the plans of our men in production. It will mean the development of special tools, short-cuts and equipment which, I believe, the flat-rate system will develop. After all, we simply have a business situation to face in service, which involves a diagnosis of the trouble, the sale of the job at the contract price and prompt delivery.

CHARLES M. MANLY:—I agree with what has been said. The important feature is that the fundamentals back of this proposition are building up in the minds of the persons buying this service the idea of integrity and efficiency. Integrity is not worth much without efficiency and efficiency is not worth much without integrity; but if we can put across a combination of the two with the man who pays for this service, I think it makes very little difference whether it is a flat-rate system, a cost-plus system or some other system. The fundamental principle of the whole proposition lies in building up in the mind of the customer, whether he be a large or small customer, the feeling that there are both efficiency and integrity. I thoroughly agree with Mr. Rognon's remarks in regard to quotations on service work. When the service plans and work have been thoroughly laid out so that the man who is performing the work does it with as high a degree of efficiency as that at which the man at the factory is compelled to work to hold his job, service will be a real business proposition.

H. C. TRENT:—I am connected at present with both sales and service. When engineers and service-men get together, they are more or less inclined to call each other good fellows; nevertheless, frank statements and constructive criticism do us all much good. Mr. Lord's paper states that considerable help can be given to service-stations by standardizing on parts, so far as possible, and by discontinuing the constant changes in the design of such units as windshield frames, fenders, tire carriers, splash pans, and the like, which make it necessary to carry an extensive stock of these parts. At present, it is necessary for the owner who patronizes the parts department and the service-station, to know the serial number of his car, the model and the like, before he can be assured of getting the particular fender or splash pan used on his car. He may know the serial number and model, but it is very doubtful if he knows anything about the series, and other details. If he does not happen to have this information with him, or if he has sent someone to make the purchase for him, it necessitates his either going without the part or guessing at what is required; perhaps he finds out later that it is the wrong part, and this means that it must be returned for exchange. The result is a loss of time and money and a loss of the owner's confidence in the service-station. If we can eliminate this condition through the assistance of

the engineers, it will not only help service but also increase sales. I believe that closer direct contact between the engineers and the service-men in the field would be of great benefit.

AZEL AMES:—I think it safe to say that 10 years ago, the average owner of an automobile was not fit to be trusted, even in broad daylight, with an egg-beater, so far as his mechanical skill was concerned; but, in these days, when our children are talking about the merits of different types of radio apparatus that their parents do not understand, we may have some hope that the customer, the automobile owner, will have perhaps a greater realization of the properties of the transportation he is using and of the difficulties incident to its production, sale and maintenance.

The manufacturers, the dealers and the service-men are well organized. One reason they are organized is because it protects their individual interests; another reason is that it is easier to cooperate in this manner than to do so with a very great number of individuals. It may be that the manufacturer, the dealer and the service-man can work with the owner better if they work with the organized owner; certainly, those who are connected with the automotive industry know that for more than 20 years the American Automobile Association has represented the organized motorist, the customer, the man who furnished the automotive industry its bread and butter.

There is a glorious opportunity for the organized producer to work with the organized consumer. In behalf of the Metropolitan Division of the American Automobile Association I can say that, at least, we are on the job to work with the automotive industry; we are standing absolutely for the enforcement of the law and we do not ask for any special favors. We want a fair show for the motorist, in legislation, in taxation, in repair bills and in charges for fuel. We will work with the automotive industry, and we want it to work with us.

R. H. WOODHULL:—We also have been using the flat-rate system. If nothing else is accomplished, it brings an executive in close touch with his organization, regardless of the benefits it may have for the customer. Flat-rate costs properly computed show the actual performance in both speed and skill of the personnel. They show in dollars and cents how the individual is doing his part of the work. So far as the owner is concerned, often, when he has been promised his car for a certain day, the service-man telephones to say the job will not be finished until several days later. This puts the owner in a bad frame of mind. Then, if the charge is larger than he expected, there is bound to be dissatisfaction; but, if the owner leaves his car with a definite understanding as to the price he must pay and knows when he can expect it finished, he is well satisfied.

I often think the designing engineer has overlooked the fact that he may design something which is mechanically perfect but still not fool-proof. This is borne out by the fact that many models which proved satisfactory under factory road-tests are found to be sadly lacking when placed in the hands of the inexperienced owner. If the car has to be changed, it is because the man into whose hands it has been placed has not given it a chance; hence, a change has to be made to lubricate a certain part automatically or increase the strength of some part or assembly so it will not fail under abuse. Therefore, the closer the designing engineer gets to the ultimate user, the faster he will eliminate his troubles.

ETHELBERT FAVARY:—If I were a service-man, I would ask the engineer why it is that before it is possible to examine the crankshaft bearings of a certain truck it is necessary to take off the lower half of the crankcase. Moreover, before this can be done the body bolts must be loosened to get at the radiator bolts to remove them; then, one end of the engine must be lifted up with a hoist and, after some jockeying and shoving the engine over, it is possible to lift it up and get at the crankcase. In another case, if the front spring should happen to break, usually the crankcase breaks also as it would hit the front axle. In another design, when it becomes necessary to repair certain rear-axle parts, they are not accessible, although visible, and it is necessary to remove the entire rear-axle. There is no necessity for such inaccessibility, as the design can be rectified without sacrificing any advantages.

The engineers with the smaller companies complain that, when they are told to redesign the product, they are expected to do it in a few weeks; to do this and at the same time embody the improvements suggested in an efficient manner is often impossible. However, the company demands and insists on coming out with a new model by a certain time and hence does not allow sufficient time to the engineer for a first-class job.

I agree with Mr. Lord that there should be closer cooperation between the engineer and the service-man, but the engineer is of course responsible for the design and must use his judgment as to what is right and what is wrong.

S. M. WILLIAMS:—There is a very direct and definite obligation on the part of the selling departments to cooperate with the engineer. That can be brought about by a keener appreciation of the engineering problems and closer observation and a better understanding of the service problems.

E. A. MOREE:—It would be a source of great encouragement to most owners to know that the problems which face them on the mean end of a service bill are being considered in the broad-minded way in which they are being dealt with at this meeting. It would help us all if the purchasers of service could know that their service problems are receiving attention from men who approach them with the broad-gaged vision that has been evidenced here.

The service on automobiles has so improved within the last 10 years that it is not comparable with the service of 10 years ago. As a purchaser of service, when I get a bill with a flat charge on it that I can compare with a previous bill containing similar charges, I feel that I am buying something perfectly definite; while I may possibly be paying somewhat more than if charged the average price, I know that I am getting something for my money and that it is the same thing that I will get in the future if I happen to come in and have the same thing done. As the acting executive of the Automobile Merchants Association, this meeting has been an enlightenment and a gratification to me. When the message of this and future meetings gets to the purchasing public, as it is bound to do if the spirit of this gathering continues, it will reduce selling resistance and increase greatly the satisfaction that owners get from their cars.

E. J. RABIDOUX:—We find in general that we are getting fair cooperation between the engineers and the service-men, but I believe it can be improved greatly. We had a National Automobile Show in New York City recently that many automotive engineers attended. I have wondered how many of those engineers went to visit their service departments here in New York City, which probably has the largest service-department organization of any city in the United States. How many

such as the relining of brakes, I find it makes no difference whether the owner has run the car 10,000 or 5000 miles, for, if the brake is worn sufficiently to require relining, the bands must be removed and the rivets cut off with a chisel and that requires a given amount of time and material. The same principle can be applied to engine bearings. Suppose one man takes exceptionally good care of his car and another man neglects his car. The latter must have the bearings taken up more frequently than the former. As Mr. Lord has said, if tools and pullers designed for the work are available, the shop mechanic can perform the needed operation consistently, regardless of the condition in which he may find the parts. It makes no difference whether the shackle bearing or bolt comes out easily or not, once a good puller is applied to it. A frozen shackle comes out very easily.

There is only one way in which a fixed-charge system of prices can be carried on successfully in a service repair-shop; it is by organizing the shop and the cost-accounting department properly, so that the cost can be kept accurately and consistently. By organizing the shop I mean the specializing of the work of the shop mechanics for, by specializing alone, can one expect a mechanic to become efficient. Tool equipment is also one of the very important factors, as poor tools not only hold-up the work but demoralize the mechanics. It is believed that if all owners whose cars have been serviced in our shops were requested to state their preference, not more than 5 per cent would ask for a return to the old system.

CHAIRMAN LEE J. EASTMAN:—In the old days, the engineer knew it all. If a truck or a car broke-down and the engineering department was told about it, the reply would be, "That cannot happen. From an engineering standpoint, the machine is built right; it cannot break." However, among the very hopeful signs is the fact that both the engineers and the service-men admit that they do not know it all. That is a sign they are both learning.

One of the other encouraging features is that the engineering departments of our various factories are becoming more and more merchandising engineers. In the old days, it was customary to build a model without consulting the distributing organization and to send it out and say, "There it is! Sell it!" It made no difference whether the model met the public demand or whether the resistance in selling it was extremely keen, the engineer felt it was right and what the public ought to have. It was difficult indeed to sell some of those models.

We see a very strong tendency now for the engineering department to consult more and more with both the service and the distributing organizations to ascertain whether, if it should build a certain type of model with certain features, there would be a ready sale for it.

One of the main factors that exists to the detriment of service consists of broken promises. If I am told that I will have my car repaired and ready at a certain time, nothing will exasperate me more than to receive a telephone message that I cannot have the car until several days later. Our service departments should strive to be sure that they do not make promises they cannot keep.

Another thing regarding which our service departments are extremely negligent is the matter of "selling" the service that we have. I am pretty well sold in favor of the flat-rate system, but I think we still have to sell it to the public; and, more than selling the flat-rate system to the public, we should sell what is back of the flat rate and show why the flat-rate system is better for the customer, the efficiency that has been brought into our service department that has enabled us to put out a flat-rate that is fair, and the like.

Thickness and Resistance of Oil-Films in High-Speed Bearings[1]

By Dr. Gerald Stoney, R. O. Boswall and J. Massey *Illustrated with* Drawings

ALTHOUGH the problem of efficient lubrication has been made the subject of considerable investigation during the course of the last few years, it is a noticeable fact that while the theoretical side of the work has received extensive development, notably from Osborne Reynolds, Sommerfield, Michell and Martin, the experimental side, represented by the researches of Tower, Stribeck and Lasche among others, has been confined entirely to measurements of pressure distribution, temperature changes and shear or frictional resistance, no direct attempt having been made apparently to determine experimentally the actual thickness of an oil film or to discover in what way this thickness changes with variations in the load, the rubbing speed and the viscosity. With the express object of filling this gap in what must of necessity be regarded as a subject of increasing practical importance, owing to the recent rapid developments in turbine construction, an experimental investigation of an essentially preliminary character has been carried out during the past year at the College of Technology, Manchester.

The apparatus employed was designed specially for the purpose, and the measurements of the oil-film thickness

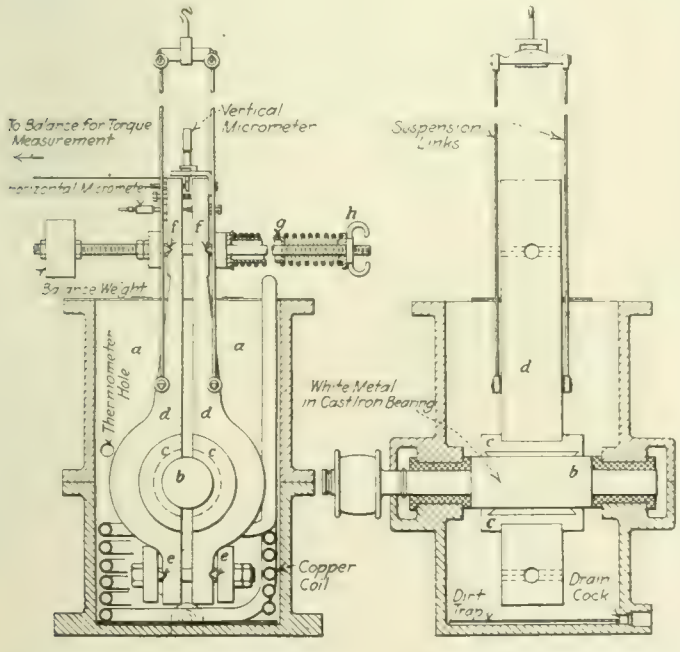


Fig. 1—Front and Side Elevations of a Machine Developed in England To Measure the Thickness and Resistance of Oil-Films in High-Speed Bearings

and the shear or frictional resistance that have been obtained from it up to the present appear to be of sufficient interest to justify their publication. The apparatus, which is shown in Fig. 1, consists essentially of a cast-iron casing *a*, provided with two gun metal bearings in which runs the mild steel journal *b*, speeds of from 2500 to 6000 r.p.m. being obtained by a belt drive from a small electric motor. The central portion of the journal, 2½ in. in diameter, is embraced by two opposing symmetrically-shaped white metal bearings *cc*, each 4 in. long and carefully scraped to fit the journal as exactly as possible over an arc of contact of 90 deg. These bearings are secured to two arms *dd*, which are held together by two independent links provided with knife-edge attachments. The lower pair of these knife-edges *ee*, are maintained at a fixed distance apart, while the upper pair *ff* are relatively movable, being controlled by the calibrated spring *g*, which can be compressed by the wing nut *h* so that any desired pressure can be exerted by the bearings on the journal, the lower knife-edges acting as a fulcrum. The weight of the arms and their various fittings is counterbalanced by a four-rod suspension to relieve the journal of all vertical pressure, the position of these points of suspension on the arms being chosen so as to maintain just sufficient rotational stability about the journal axis to keep the arms in their normal vertical position, while not interfering with possible displacement of the arms relative to one another.

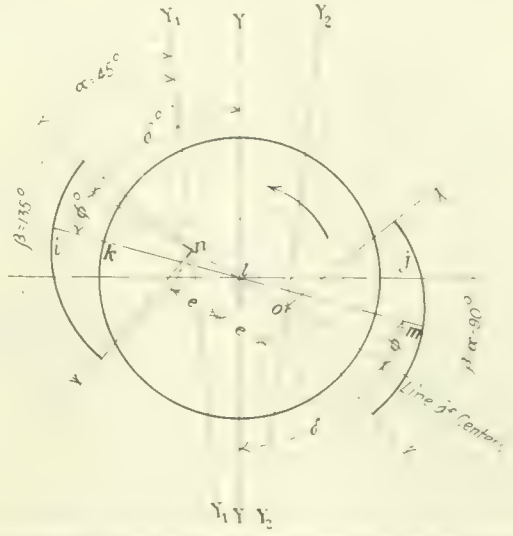
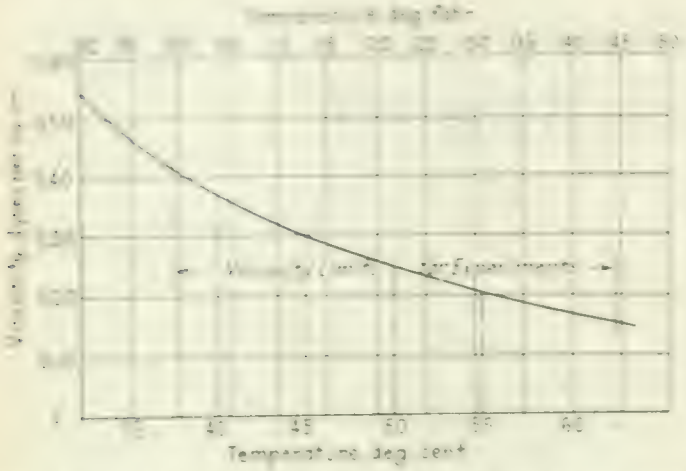


Fig. 2—Diagram Illustrating the Principle upon Which the Machine Operates

The casing is filled with oil to a level of about 3 in. above the top of the journal, a copper water circulation coil being inserted in the lower half of the casing to facilitate temperature regulation. The method of operation of the apparatus is briefly as follows: Referring to Fig. 2 and assuming that the two white metal bearings *i* and *j*, are initially in contact with the journal and under the influence of pressure due to the spring, a rotation of the journal in the direction indicated will result in a wedge-shaped film of oil being introduced between each brass and the journal, the thickness of this film being dependent upon the pressure, the rubbing speed and the viscosity of the oil. The formation of this film

[1] Reprinted from *Engineering* (London).



will necessarily be accompanied by small displacements of the arms holding the brasses, the only restraint to the relative motion being that supplied by the spring. The motion of each arm may, in fact, be considered as combined of a translation parallel to the vertical axis Y Y and an angular rotation through an angle γ about the lower knife-edges.

To measure these relative displacements, shown much enlarged in the figure, two micrometers, one vertical and the other horizontal are fitted at the end of the arms, the measurements thus obtained enabling the actual displacement of the brasses relative to the journal and the thickness of the film to be calculated. The shear or frictional resistance was determined by the measurement of the horizontal force required at the end of the arms to counteract the turning effect about the journal axis and maintain the arms in their normal vertical position.

It will be seen that if Φ represents the angle between any radius of the journal l and the lines joining the center of the journal l to the displaced centers n and o of the brasses, the thickness of the film at this point will be given by the formula

$$t = e \cos \Phi$$

where e is the eccentricity or distance between the center of the journal and the center of the brass. Also, if α is the angle between the line of centers and the vertical axis Y Y, the thickness of the oil film at the inlet and the outlet will be given by the formulas

$$t_1 = e \cos (\alpha - \delta)$$
$$t_2 = e \cos (\beta - \delta)$$

The values for e and α can be calculated from the micrometer measurements and the known dimensions of the

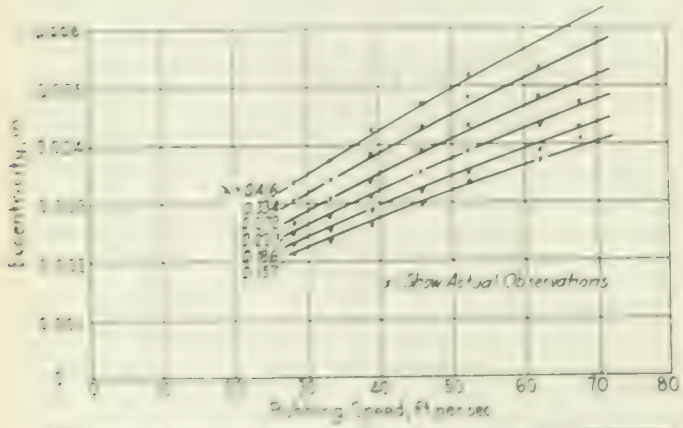


Fig. 3—Nomogram That Was Constructed To Enable the Values of Eccentricity To Be Determined Easily

apparatus. The oil used throughout the tests was Price's geared turbine oil, having a specific gravity of 0.88 at 60 deg. fahr. The viscosity was determined in the first instance by a Michell viscometer having a constant 14.4, the results obtained thereby being checked by an additional series of observations made with a standard Redwood instrument, a calibration formula being applied to reduce the times of outflow to absolute units of viscosity or dynes per square centimeter, as given directly by the Michell instrument. The agreement between the two methods was very satisfactory and the viscosity-temperature curve is shown in Fig. 3, the relationship between the two variables over the temperature range

used being expressed to a close approximation by the formula:

$$\lambda = 1980 \div (T - 32)^2$$

where

λ = viscosity in dynes per square centimeter
T = temperature in degrees fahrenheit

The procedure adopted when taking observations was briefly as follows: The oil, brought to the required temperature by the rotation of the journal with the spring set for some convenient load, was maintained at this temperature by regulating the flow of cooling water through the coil until the whole apparatus had become correspondingly warmed up. The journal was then stopped and the spring correctly adjusted to give the desired test load on the brasses. Initial zero readings having been taken, the journal was restarted and measurements made for a series of gradually increased speeds, at the end of which the journal was stopped and zero readings again taken as a check.

An analysis of the complete set of results indicates that within the limits of the experiments which were from 39.5 to 117.5 lb. per sq. in. for load; 28 to 67 ft. per sec. for rubbing speed; and 0.416 to 0.157 centimeter-gram-second units for viscosity, the eccentricity e and the intensity of shear, ρ, or its equivalent $\mu\rho$, may be expressed to a very close degree of approximation by the formulas

$e = 0.00986\ [(\lambda^{0.46} V^{0.71}) \div P^{0.75}]$ inches
$\rho = 0.0370\ \lambda^{0.420} \cdot V^{0.475} \cdot P^{0.375}$ pounds per square inch

where

λ = the viscosity in dynes per square centimeter
V = the rubbing speed in feet per second
p = the intensity of pressure on the brasses in pounds per square inch

The intensities of pressure and shear are reckoned on the full projected area of the journal, 10 sq. in. In putting forward these formulas we reserve, until more complete data are available, the divising of rational formulas which shall be applicable to all similar bearings, and they are put forward merely as a compact method of recording the actual observations. These formulas do not compare unfavorably with the purely theoretical formulas

$$e = cV(\lambda V \div P)$$
$$\rho = KV(\lambda VP)$$

the discrepancy affecting the indices being possibly attributable to the combined effect of the lateral flow or side leakage and the variation of the viscosity along the arc of contact due to the rise of the temperature of the oil film, both of which factors are neglected in the simple theoretical treatment.

It is important to notice, however, that both the experimental and theoretical formulas are in agreement respecting the dependence of shear on the load, this fact being in direct opposition to the usually accepted statement that the shear is independent of the pressure.

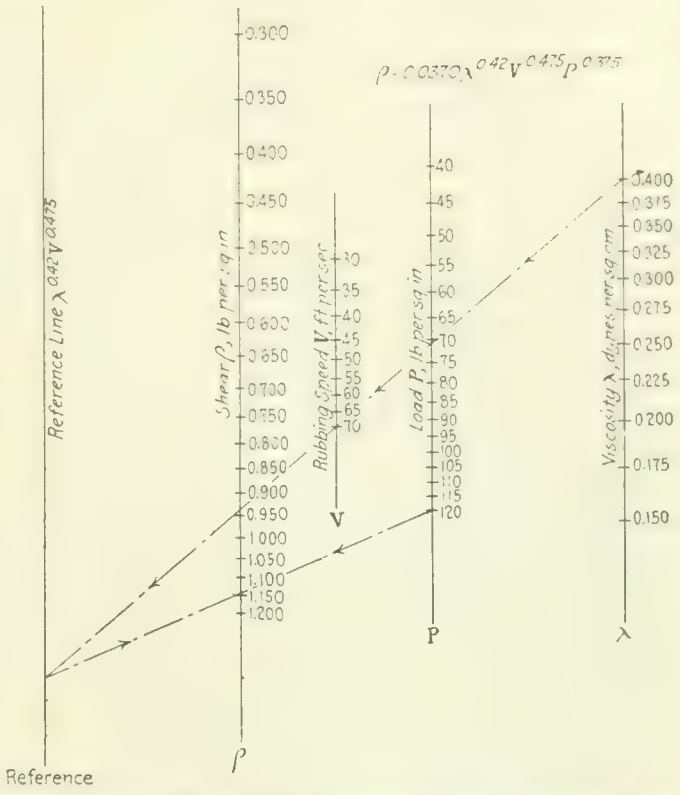


FIG. 6—VALUES OF SHEAR CAN BE DETERMINED READILY BY THE USE OF THIS NOMOGRAM

A further point of interest is that the position for the line of centers with reference to the vertical axis Y Y appears to be independent of the load and speed and only slightly dependent upon the viscosity, the angle only altering 3 deg., from 66 to 63 deg., as the viscosity changes from 0.416 to 0.157 dynes per sq. cm. The ratio between the inlet and outlet thickness of the oil film shows a corresponding change from 2.6 to 3.0.

The results obtained for a total load of 592 lb., corresponding to 59.2 lb. per sq. in. on the bearing, are shown in Fig. 4, the curves being drawn to correspond with the experimental formulas given above. Similar sets of curves were obtained for the four other loads that were tested. In addition two nomograms, Figs. 5 and 6, have been constructed for the easy determination of values for eccentricity and shear for any combination of λ, P, and V.

The experimental work described is at the moment being extended further to investigate the effects of varying the arc of contact, the length of the bearing and the diameter of the journal. It is hoped that these additional tests will help to throw more light on what is unquestionably a difficult and complicated subject.

EFFECT OF OXYGEN UPON FORGING PROPERTIES

A SHORT series of iron-sulphur-manganese alloys has been prepared by melting under air at the Bureau of Standards, for comparison with a portion of a similar series prepared in the Arsem vacuum furnace, to determine whether the presence of oxygen in the alloy influences the sulphur limit and the manganese-sulphur ratio for successful forging. It has been necessary to develop a new type of refractory crucible for use in preparing the carbon alloys of the vacuum-fused series of this investigation. Manganese crucibles are not desirable on account of the slagging out of the sulphur. Zirconium silicate crucibles served satisfactorily for the preparation of the iron-sulphur and iron-sulphur-manganese alloys, but with the addition of carbon, the alloys are contaminated by silicon. Tests are now in progress to determine the suitability of a crucible the chief constituent of which is zirconium oxide.

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

ONE-WIRE SYSTEM FAVORED

Truck Builders Recommend Elimination of Standard Two-Wire System

At the last meeting of the Lighting Division, it was considered advisable to obtain an indication from the motor-truck builders as to the service obtained with bases, sockets and connectors conforming to the S. A. E. standards for one and two-wire systems for electrical apparatus on gasoline trucks. The information obtained as a result of circularizing the truck companies showed that they are practically unanimous in favoring the one-wire over the two-wire system, several manufacturers using the two-wire systems indicating a preference for the one-wire system. The replies to the question as to whether a standard should be continued for both systems indicated a decided preference for retaining only the one-wire or ground-return system.

As the present standards had been criticized from time to time to the effect that they do not stand-up under severe truck service, information was requested on what troubles had been experienced. The principal difficulties reported were poor workmanship and poor ground connections. One or two manufacturers believed that the present standard sockets were too small for motor-truck applications.

Through the American Petroleum Institute comments were received from the Advisory Committee on Fire Prevention and Protection to Life and Property as to the use of the one-wire and two-wire systems for gasoline tank trucks which showed the refiners are evenly divided as to which system should be used. The argument was advanced by several that the two-wire system gives little more protection from short-circuits than the one-wire system on the basis that if one wire becomes grounded there is no indication of such a ground, with the result that the system becomes practically a one-wire system, another ground on the opposite side of the circuit already grounded causing a short-circuit.

SIX-POINT CARBON RANGE DISCUSSED

Iron and Steel Division Decides Change in 10-Point Range Is Not Desirable

The suggestion that the 10-point carbon range in the present Iron and Steel Specifications should be changed as described in full in the May issue of THE JOURNAL was discussed at length at the May meeting of the Iron and Steel Division but no decision was made other than to lay the subject on the table in view of the absence of proponents of the six-point carbon and alloy ranges. General discussion indicated that whereas the narrowing of the carbon range was a desirable one from a metallurgical standpoint and one that could be practically employed by those manufacturers purchasing in such large quantities as to permit selection at the mill, in the case of the average steel purchaser who used only a limited range of compositions the application of such narrow limits might introduce serious purchasing and delivery troubles. It is expected that the subject will be discussed in further detail at subsequent meetings of the Division.

The subject of high-carbon steel was discussed at the last meeting, the subject having been assigned to the Division by the Council. In order to facilitate the work of the Division, B. M. DeLong, of the Carpenter Steel Co.; H. J. Stagg, of the Halcomb Steel Co., and R. H. Davis, of the Sterling Steel Co., were appointed a Subdivision to prepare a preliminary report.

HIGH NUTS AN AID IN SERVICING

Nuts Higher Than S. A. E. Standard Developed to Increase Accessibility

The present S. A. E. Standard plain and castle nuts are designed so that the height permits sufficient thread to develop a shearing strength equivalent to the tensile-strength of the bolt. It has been found, however, that when the standard nuts are used in more or less inaccessible places it is extremely difficult to obtain sufficient hold with a wrench to permit easy removal or to obtain the proper tightness.

A type of nut has therefore been developed by engine builders that has a height considerably greater than that of the standard nut. Experience has shown that the use of these special nuts, sometimes called "high nuts," are of considerable value from a servicing point of view and facilitate assembly.

The advisability of establishing a definite standard for such nuts has been referred to the Screw-Threads Division. To determine to what extent these special nuts are used in practice, the Standards Department has circularized manufacturers and users for information as to present practice.

STORAGE-BATTERY REVISIONS PROPOSED

Division Acts on Automotive Simplified Practice Committee's Recommendations

At a meeting of the Storage-Battery Division held on May 17 recommendations were received from the Automotive Simplified Practice Committee as a result of a survey made of the storage-battery situation in the automotive industry. The survey, which indicated that over 85 per cent of the batteries used conform to the present S. A. E. Standard for storage-battery dimensions, was made in pursuance of the work of reviewing the extent of use of the more important automotive standards that affect replacements, in an effort to further their adoption in practice.

The Automotive Simplified Practice Committee recommended that the Storage-Battery Division establish definite storage-battery compartment lengths that would be satisfactory for the standard storage-battery sizes, the length being selected so that batteries of larger capacity than the original equipment might be used if desired; that the Storage-Battery Division review the present S. A. E. Standard to determine if any revisions are desirable; that definite dimensions for the hold-down device be included in the existing standard; that the Division circularize all automobile companies to determine if they are using the storage-battery compartment dimensions to be recommended and, if not, if it will be possible for them to use such dimensions in future production.

As the result of these recommendations, the Division pro-

posed the following revisions in the existing S. A. E. Standard for Storage-Batteries, p. B23 of the S. A. E. HANDBOOK:

Storage-battery compartment lengths shall be 11, 12⅝ and 13½ in.

The depth of storage-battery compartments measured from the bottom of the compartment, not from the top of the wood strips in the compartment, shall be 10⅜ in.

Hold-down devices shall be attached at the top of each end of the battery case, not at the top of the handles.

The hole for the battery hold-down rod shall be ⅜ in. in diameter, located on the center-line of the battery and 3/16 in. from the end of the battery case. The maximum overall lengthwise dimension of the hold-down device shall be 17/32 in.

Battery sizes Nos. 4 and 9, which are no longer used as original equipment, shall be eliminated.

MOLYBDENUM STEELS

The subject of standardization of molybdenum steel, assigned to the Iron and Steel Division by the Council, was discussed at the last meeting of the Division. In order that information might be obtained as to present practice and tentative specifications for chemical compositions formulated, the subject was referred to the Subdivision on Chromium and Chromium-Vanadium Steel, of which M. H. Schmid, of the United Alloy Steel Corporation, is chairman.

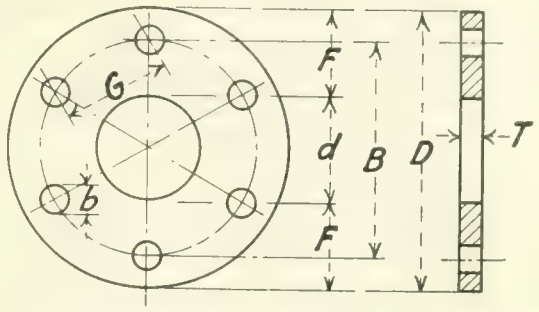
FLEXIBLE-DISC STANDARD PROPOSED

Tentative Subdivision Report on Universal-Joint Flexible Discs Circularized

At the present time an unnecessarily large number of universal-joint flexible-discs are in general use, owing to the unguided development of this unit. This condition naturally worked an undue hardship upon the flexible-disc manufacturers, as well as in servicing. Appreciating these conditions, the Parts and Fittings Division appointed a Subdivision, consisting of C. W. Spicer, of the Spicer Mfg. Corporation, and E. W. Templin, of the Goodyear Tire & Rubber Co., to review the situation and submit a preliminary recommendation as to what flexible-disc dimensions should be included in an S. A. E. Standard, provided it should be desirable to formulate one.

As a result of considerable study of present practice and the fundamental conditions under which universal-joint flexible discs operate, the Subdivision submitted a series of nine sizes of flexible disc and corresponding torque ratings, the sizes being in accordance with the most desirable engineering practice. The preliminary recommendation is given in the accompanying table.

In submitting the report, the Subdivision states that the maximum and average torque to be transmitted through the disc should not exceed that specified if the most efficient service is to be obtained. The maximum torque rating is



Nominal Size	Outside Diameter D ±0.030	Inside Diameter d ±0.030	Bolt-Circle Diameter[1] B ±0.015	F	G ±0.010	Bolt-Hole Diameter b +0.000 −0.010	Thickness T[1] +0.030 −0.010	Torque Ratings, Lb-In. Per Disc	
								Maximum	Average
6 x¼	6.000	2.250	4.625	1.875	2.3125	0.500	0.250	910	225
6½x¼	6.500	2.375	5.000	2.000	2.500	0.500	0.250	1,060	260
6½x5/16	6.500	2.375	5.000	2.000	2.500	0.500	0.313	1,320	330
7 x5/16	7.000	2.625	5.250	2.125	2.625	0.500	0.313	1,520	380
7½x5/16	7.500	2.750	5.625	2.375	2.813	0.500	0.313	1,740	430
7½x⅜	7.500	2.750	5.625	2.375	2.813	0.500	0.375	2,080	520
8 x⅜	8.000	3.000	6.000	2.500	3.000	0.625	0.375	2,360	590
8½x⅜	8.500	3.000	6.250	2.750	3.125	0.625	0.375	2,650	660
9 x⅜	9.000	3.250	6.500	2.875	3.250	0.625	0.375	2,950	740

[1]The thickness of a single disc shall not vary by more than 0.020 in.

based on an allowable stress of 325 lb. per sq. in. of cross-section of the disc, and the average torque rating is based on a stress of 80 lb. per sq. in. The ratings are intended for normal conditions of speed and alignment, it being stated that in general discs will not give good service in installations where the angle between the shafts exceeds 7 deg.

At the request of the Subdivision the Standards Department submitted copies of the preliminary report to manufacturers of flexible discs and users of flexible-disc universal-joints, requesting definite comments on the following points:

(1) The desirability of the standardization proposed.

(2) Whether the list of suggested sizes would meet all probable requirements of the industry.

(3) Objections to any dimensions or sizes specified, together with the definite recommendations as to substitutions.

(4) Objections to any of the torque ratings proposed, together with definite recommendations as to substitutions.

The Subdivision will review the preliminary report in the light of all comments received and the report, revised if found desirable, will then be submitted to the members of the Parts and Fittings Division in accordance with the regular standardization procedure.

OBITUARY

WILLIAM W. DEAN, an electrical engineer for the United States Cartridge Co., Lowell, Mass., died of heart failure on May 3, 1923, while in New York City on a business trip, aged 59 years. He was born July 8, 1863, at Fairfield, Iowa.

Following his general education he was an engineer for the Bell Telephone Co., St. Louis, from 1882 to 1897, and for the American Telephone & Telegraph Co., Boston, from 1897 to 1898. He was chief engineer of the Kellogg Switchboard & Supply Co., Chicago, from 1898 to 1900, and experimental engineer for the Western Electric Co., Chicago, from 1900 to 1904. Becoming president and chief engineer of the Dean Electric Co., Elyria, Ohio, in 1904, he continued this connection until 1911 and then was vice-president and chief engineer of the Dean Auto Devices Co., Chicago, until 1914.

As a consulting engineer, he was connected with the Stromberg Carlson Telephone Mfg. Co., Rochester, N. Y., from 1914 to 1915, and with the Splitdorf Electrical Co., Newark, N. J., following 1915, where he designed and developed inventions pertaining to electrical equipment for automobiles. Subsequently, his activities continued along consulting electrical engineering lines in Stamford, Conn.; Newark, N. J., and Chicago, until he associated himself with the United States Cartridge Co. Throughout his career, he specialized in electrical invention and design. He was elected to Member grade in the Society, Jan. 10, 1917.

Applicants *for* Membership

[illegible] applications for membership received between May 15 and June 15, 1923, are given below. The members of the Society are urged to send any pertinent information with regard to these men which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

[illegible]

[illegible] CARLOS, MENELEO G., student, Cornell University, *Ithaca, N. Y.*

[illegible]

[illegible]

[illegible]

Applicants *Qualified*

The following applicants have qualified for admission to the Society between May 10 and June 9, 1923. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ADAMS, JAMES R. (M) superintendent of research department and plant metallurgist, Nicetown plant, Midvale Steel & Ordnance Co., Philadelphia, (mail) *Hatboro, Pa.*

ALEXANDER, DONALD (M) Edward G. Budd Mfg. Co., *Philadelphia,* (mail) 121 West Springfield Avenue.

ANDERSON, J. A. (E S) student, University of Minnesota, *Minneapolis,* (mail) 1211 Seventh Street, South.

BALLENTINE, WILLIAM I. (M) vice-president, Advance-Rumely Co., *LaPorte, Ind.,* (mail) 1402 Indiana Avenue.

BEELER, WILLIAM RUSSELL (E S) student, University of Michigan, *Ann Arbor, Mich.,* (mail) 514 Cheever Court.

BELLOWS, LYMAN H. (A) Detroit sales office, Walden-Worcester, Inc., Worcester, Mass., (mail) 5-107 General Motors Building, *Detroit.*

BENÉT, LAURENCE V. (M) vice-president, Societe Anonyme des Anciens Establissements Hotchkiss & Cie, St. Denis, Seine, France, (mail) 22 Rue Caumartin, *Paris, France.*

BLACKMORE, CHARLES C. (A) owner, Charles C. Blackmore Co., 1015 East Fifth Street, *Dayton, Ohio.*

BOWMAN, JOHN ALDEN (A) comptroller in charge of finances and general management, John W. Brown Mfg. Co., *Columbus, Ohio.*

BROOKE, HAROLD LEE (J) sales and service engineer, C. G. Spring Co., *Detroit,* (mail) 2736 Virginia Park.

BURKE, EDMUND L. (A) technical correspondent, Moto-Meter Co., 15 Wilbur Avenue, *Long Island City, N. Y.*

CARTER, H. A. (A) vice-president and sales manager, George R. Carter Co., *Connersville, Ind.,* (mail) 1818 Indiana Avenue.

CATLIN, AUREL A. (E S) student, Michigan Agricultural College, *East Lansing, Mich.,* (mail) Dorian House.

CONE, LOGAN J. (E S) student, University of Cincinnati, Cincinnati, (mail) 220 South C Street, *Hamilton, Ohio.*

COWAN, GERALD A. (E S) student, University of Cincinnati, Cincinnati, (mail) 2967 Sheridan Avenue, *Detroit.*

CRAIN, ALLAN MEYER (E S) student, University of Cincinnati, *Cincinnati,* (mail) 5811 Glenview Avenue.

DAVIS, LEWIS K. (M) managing director, Roadless Patent Holding Co., City of Washington, (mail) 10 East Kirk Street, *Chevy Chase, Md.*

DESROCHES, PHILIP W. (J) special student, Ford Motor Co., Highland Park, Mich., (mail) 612 Ferry Avenue, East, *Detroit.*

DIBBLEE, WALTER AUGUSTUS, JR., (E S) student, University of Cincinnati, *Cincinnati,* (mail) 2624 Scioto Street.

DONNER STEEL CO. (Aff) *Buffalo.*
Representatives:
Greenameyer, A. G., assistant to general superintendent.
Vosmer, W. F., general manager of sales.

DRUMM, EDGAR A. (A) principal, Y. M. C. A. Automobile School, 1736 G Street, Northwest, *City of Washington.*

DUBOIS, CHESTER B. (M) mechanical engineer, Jones Speedometer, Inc., New Rochelle, N. Y., (mail) 313 Wolfs Lane, *Pelham, N. Y.*

DUNNING, LEIGHTON (M) assistant to president and engineer, John Warren Watson Co., 24th and Locust Streets, *Philadelphia.*

DUPONT, V. H. MEYER (A) founder, publisher and sole owner, Publication Office, 5 Hongkong Road, *Shanghai, China,* (mail) Box 994 United States Post Office.

FROST, LEON E. (E S) student, University of Michigan, *Ann Arbor, Mich.,* (mail) 510 Cheever Court.

GAGE, N. E. (A) sales manager, National Tool Co., West 112th and Madison Avenue, *Cleveland.*

GLEASON, FRED H. (M) chassis lubrication experimental engineer, Bowen Products Corporation, *Auburn, N. Y.* (mail) 197 Genesee Street.

GRAY, JOHN S. (E S) student, University of Utah, *Salt Lake City, Utah,* (mail) 230 Fifth Street, East.

GREENWALD, H. A. (J) research assistant, Cadillac Motor Car Co., *Detroit,* (mail 2539 West Grand Boulevard.

HAIGH, JAMES HAROLD (E S) student, Michigan Agricultural College, East Lansing, Mich., (mail) 812 West Shiawassee Street, *Lansing, Mich.*

HANSELL, HOWARD FOSTER (E S) student, University of Cincinnati, Cincinnati, (mail) Elmo Place, *Middletown, Ohio.*

HAWLEY, FRANK M. (M) engineer, Detroit branch, Morse Chain Co., Grand River Station, *Detroit.*

HOFFMAN, E. E. (M) chief engineer, Hendee Mfg. Co., *Springfield, Mass.,* (mail) Oaks Hotel.

HOLLAND, MAURICE (M) director of the division of engineering, National Research Council, 29 West 39th Street, *New York City.*

INGERSOL, AUSTIN OLIVER (E S) student, Michigan Agricultural College, *East Lansing, Mich.,* (mail) Phylean House.

JACKSON, LEE R. (A) district manager in charge of manufacturing, Firestone Tire & Rubber Co., *Detroit,* (mail) 2283 Taylor Avenue.

KERSTEN, A. EDGAR (A) road engineer, Garford Motor Truck Co., Inc., Boston, Mass., (mail) 129 Theodore Parker Road, *West Roxbury, Mass.*

KINNEY, ALDON M. (J) assistant superintendent, Fosdick & Hilmer, Union Trust Building, *Cincinnati.*

LACEY, ARTHUR H. (M) consulting engineer, Arthur H. Lacey Co., 714 Harrison Street, *San Francisco.*

LEROY, B. L. (A) engineer, Beans Spring Co., *Massillon, Ohio,* (mail) 1125 Wellman Street.

MAGRAW, GEORGE F. (J) draftsman, Packard Motor Car Co., *Detroit,* (mail) 1774 Helen Avenue.

MANBECK, PARK D. (A) advisory sales engineer, National Carbon Co., Inc., Cleveland, (mail) 1833 Brightwood Street, *East Cleveland.*

MANDEVILLE, GEORGE, JR., (E S) student, University of Cincinnati, *Cincinnati,* (mail) 1303 Michigan Avenue.

MASON, OSCAR E. (J) block test foreman, International Motor Co., *Plainfield, N. J.,* (mail) Pleasant Avenue.

MEYER, HENRY F. (M) truck equipment engineer, Van Dorn Iron Works Co., *Cleveland,* (mail) 4569 East 49th Street.

MONK, MARVIN E. (A) assistant sales manager, U. S. Ball Bearing Mfg. Co., Chicago, (mail) 807 North Lombard Avenue, *Oak Park, Ill.*

MOORE, IRA A. (A) in charge of repair department, Reliance Mfg. Co., *Cedar Rapids, Iowa,* (mail) 428 First Avenue, West.

MORRISON, J. B. (A) assistant chief engineer, Durant Motors Co. of Canada, Leaside, Ont., (mail) 415 Melbourne Avenue, *Detroit.*

MORTON, ANSEL N. (A) in charge of building and testing engines, International Motor Co., Plainfield, N. J., (mail) 181 Grove Street, *North Plainfield, N. J.*

MURRAY, JOHN B. (E S) student, Georgia School of Technology, *Atlanta, Ga.,* (mail) 176 West North Avenue.

NAKASHIMA, CAPT. TOTARO (F M) Motor Transport Corps, Setagaya, near Tokyo, Japan, (mail) c/o Attache Militaire du Japan, Rue Eugene Manuel, *Paris,* 16e, *France.*

[illegible]

[illegible]

[illegible]

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIII August, 1923 No. 2

Chronicle and Comment

July 1923 Issue of Data Sheets

THE July issue of data sheets will be mailed to the members early in August. The issue will contain 138 pages, 50 of which are new, and is the second largest issue since the S. A. E. HANDBOOK was revised in 1920.

Instances have been brought to the attention of the Society where disagreement has been caused through the use of obsolete data sheets. Members would do well to have their books, after the new issue has been inserted, checked to the list of uptodate sheets and dates of issue that is included in the letter of transmission.

As the revised S. A. E. HANDBOOK will contain 558 pages, members may find it more convenient to use two binders, one binder being used for Sections A, B and C and the other for Sections D to K.

1906 Transactions Wanted

A COPY of the first volume of the Transactions of the Society, that for the year 1906, is desired to complete a set maintained as part of the archives of the Society. It will be appreciated if any member who has a copy of this volume and does not desire to keep it for his own library, will communicate with the offices of the Society in New York City.

Part II 1921 Transactions

THE second part of the TRANSACTIONS of the Society for the year 1921 was mailed recently to those members who placed orders for them. This volume, which completes the sixteenth issued by the Society, contained 20 papers given at Society meetings during the latter half of 1921 and included a total of 566 pages. The papers include the able treatise on gas-engine cylinder actions by Sir Dugald Clerk that marked the beginning of a greater appreciation of the value of combustion research in this country. A majority of the contents deals with various elements of the fuel problem, turbulence and combustion.

When this issue of THE JOURNAL went to press, the work of publishing the next volume of TRANSACTIONS, Part I, 1922, was well under way. Only enough copies will be printed to meet the requests of the members and no orders will be accepted for this volume after Sept. 4, 1923, when it will go to press. An order blank for the next volume of TRANSACTIONS, Part I, 1922, is included in this issue of THE JOURNAL on p. 54 of the advertising section.

Papers on Production Problems

THE Meetings Committee of the Society is particularly anxious to make the 1923 Production Meeting, which will be held at Cleveland, Oct. 25-27, at least as successful as the meeting at Detroit last October. The success of the Detroit meeting can be attributed largely to the excellence of the papers presented and the timeliness of the subjects chosen for discussion. To achieve success at Cleveland, it is recognized that current problems whose solution is urgent must again be chosen for treatment in the sessions. A canvass of production authorities is now being made to ascertain which problems are of greatest general interest. Suggestions are in order and will be received gratefully if forwarded to the office of the Society in New York City.

The interest in the problem of cutting accurate and quiet-running gears alone assured a large and appreciative audience once that topic was selected for study at the Detroit meeting. Gear-cutting still possesses the same attractiveness as a subject as it did last year and one session will be set aside for it at Cleveland. Manufacturers of gear-cutting machines are being asked to present papers recording what progress has been made in correcting the errors revealed by the 1922 meeting. Papers are being solicited from men who have been studying the causes of gear noise.

It is certain that more papers will be submitted than can be used at the Cleveland Meeting. Authors who are desirous of presenting papers can avoid disappointment by making their requests early and submitting outlines of papers on subjects that are known to be of general interest. Papers that attempt to do little but set forth the particular advantages of an individual machine are less likely to be accepted than those treating specific problems and presenting the experience and quantitative results of a carefully conducted piece of research in a reasonably unbiased manner. The probability of a paper's being accepted can be judged largely on the amount of practical workable information it presents for the attending production men to take back into the shop with them. The Society wants factory men to attend its meetings because they expect to carry home sufficient

Men and Positions

THE list of Men and Positions Available that has always been published in the advertising section of THE JOURNAL has been discontinued with this issue. This step has been necessitated by improvements made in the employment service of the Society during the past year. Under the improved system, bulletins of positions available are sent semi-weekly to members seeking employment; similar bulletins of men available are mailed to a list of representative manufacturers and to companies making specific inquiries for men. These semi-weekly bulletins have filled the positions available with such despatch that the monthly lists published in THE JOURNAL are often out-of-date before they reach the members. This condition has resulted in disappointments to several members who have written promptly to the office in New York City upon receipt of THE JOURNAL only to find that the position interesting them has been filled through the more frequent service of the bulletins.

Use of the bulletin service for a year has demonstrated clearly its superiority over the monthly lists in THE JOURNAL. Since THE JOURNAL lists can not be guaranteed as being uptodate while the semi-weekly bulletins are operating, it seems best to discontinue the publication of information that might be misleading.

Sectional Committee Reports on Screw Threads

THE Report of the Sectional Committee on the Standardization and Unification of Screw Threads has been submitted to the American Society of Mechanical Engineers and the Society of Automotive Engineers, the sponsor societies, and has been approved by the Council of the American Society of Mechanical Engineers and is being prepared by that Society in pamphlet form. The Sectional Committee was organized by the sponsors under the rules of procedure of the American Engineering Standards Committee, to review the Progress Report of the National Screw Thread Commission issued as the Bureau of Standards Miscellaneous Publication No. 42, and to report thereon to the sponsors.

The report, which is intended for bolts, machine screws, nuts, commercial tapped holes and the like, includes sections treating of Terminology; Form of Threads; Series of Threads, including tables; Classification of Fits and Tolerances.

The Council of the Society at its meeting on June 18 at Spring Lake, N. J., assigned the report to the Screw Thread Division of the Society's Standards Committee and instructed the Society's Standards Committee to submit the report to the Standards Committee in accordance with the Standards Committee regulations governing the acceptance and approval of Sectional Committee reports submitted to the Society as sponsor. It is probable that the Division will accordingly act on the report as a whole for approval by the Society as Tentative American Standards, issued under the rules of the American Engineering Standards Committee, and then report such parts of the Sectional Committee's report for adoption as S. A. E. Standards as are particularly applicable to general automotive practice. The report will be acted on in the same manner as the regular standardization work of the Society, and submitted to the Standards Committee and Society for approval at the meeting next January.

More on "Licensing" of Engineers

A GENERAL letter sent to the members recently called their attention to the fact that laws exist in a number of States providing in general that engineers doing public or private engineering work are required to register, paying fees in varying amounts up to $25 for such registration. Since sending this letter to the members, the office of the Society has been in communication with the secretaries of the various States endeavoring to secure copies of these laws and opinions on whether they affected automotive engineers. As a result, some corrections must be made in the list of States contained in the general letter to the members since, in contradiction of the original information received by the Society, some States do not require automotive engineers to apply for license.

The Secretary of State of West Virginia informs us that there is no law in that State covering the registration of automotive engineers. The Secretary of State of Illinois writes that "while bills were introduced in the present General Assembly relative to the licensing of mechanical and automotive engineers, these have not been passed and it is very doubtful if they will be passed during this session of the General Assembly." There is no State license required of professional engineers in Wisconsin, according to the Secretary of that State, attempts to pass such a law having failed at two sessions of the legislature. The State Comptroller of New Mexico informs us that there is no statute in that State which requires a license to practise automotive engineering. The State of Virginia has a law requiring the examination and the certification of architects and professional engineers, but the Secretary has written expressing doubt whether this law would be construed to cover automotive engineers. The State Board of Engineers of Oregon does not recognize automotive engineering as a branch of professional engineering at this time, according to advices from the Secretary of that State. The Secretary of State of Arizona informs us that there is a State law requiring the licensing of architects, engineers, land surveyors and assayers but there is some question about its applying to automotive engineers. A bill to repeal the licensing of engineers has passed the Senate in Pennsylvania and has gone to the third reading in the House.

The members must appreciate that it is a serious matter for the Society office to accept the responsibility of advising members whether they should register in their respective States or not. It would seem advisable for each of the members to write the Secretary of the State in which he resides or practises to secure an opinion or interpretation that carries some legal authority with it.

In response to the request contained in the circular letter sent out by the Society, letters continue to be received from the members expressing opinions on the advisability of laws requiring the registration or the licensing of engineers. Judging from the letters received, opinion is about evenly divided. It is noteworthy, however, that the majority of the engineers who have attained some prominence in the industry are opposed to this form of legislation.

Spark-Advance in Internal-Combustion Engines

By G. B. Upton[1]

Semi-Annual Meeting Paper *Illustrated with* Charts

ALTHOUGH the proper timing of the spark is as essential as the spark itself and the electrical and mechanical devices for producing the spark have been many, little attention has been given to the study of spark-advance. An error in timing of ± 20 deg. in a low-compression engine, or of ± 15 deg. in most other engines, has been shown experimentally to cause a loss of 10 per cent from the best power and economy, provided other conditions remained the same. Hand or semi-automatic control can average hardly closer than ± 15 deg. to the correct advance because the speed and the load combinations are constantly changing on the road.

Two important phases mark the spark-advance problem. The practical question as to whether the requirements of optimum spark-advance at various combinations of load and speed are such as might be controlled automatically is apparently answered affirmatively; it can be satisfactorily represented by additive functions, one of speed only and one of load or intake-suction only. Hand adjustment would still be needed to take care of the difference between a clean engine and a dirty one or of a cold engine. When once an engine has been warmed up, however, automatic controls could maintain the proper spark-advance, thereby increasing in practice the power, flexibility and economy of the engine.

The second phase is that of scientific analysis. Inasmuch as combustion takes time, and as the engine is rotating during the combustion process, spark-advance is essential, for it maintains a definite relation between the progress of the explosion and the motion of the piston of the engine. This relation should be such that half the rise of pressure during combustion would occur at the dead-center position of the piston. Analysis, however, both theoretical and experimental, shows that one-half of the pressure rise occurs substantially at three-fourths of the explosion-time, that is, the interval between the point of ignition and the pressure peak. This, then, is the numerical basis for the relations of explosion-time, engine speed and optimum spark-advance.

The existing data, relating to the explosion-time as affected by the mixture-ratio, the size of the combustion-chamber, turbulence, dilution with dead or exhaust gases and the temperatures preceding the explosion, are reviewed. Density is shown not to affect the explosion-time. The factor commonly supposed to be density, which demands an increased spark-advance as the engine is throttled, is in reality dilution with exhaust gas, which increases as the throttle closes, and the cause of the faster explosion in a high-compression engine than in one of low compression is the temperature preceding ignition.

A simple mathematical law, connecting the explosion-rate and turbulence and derived from experiments on bombs, is shown to be applicable to engines, and the manner of its application to the turbulence factor of any engine is indicated. This opens the way to quantitative experiments on turbulence in various designs of engine, hence to the development of designs for producing the greatest amount of turbulence, if such development should seem desirable, as turbulence is the factor that makes really high rotative speeds compatible with a good power output. An equally important factor in making explosions in engines occur more quickly than those in bombs is the heat produced adiabatically during the compression stroke.

The slowing-up of combustion on account of the dilution of the charge with exhaust gas was measured experimentally, and the results are tabulated and compared with the numerical extent of the dilution. Assuming that the dilution ratio is the ratio of the total charge to the quantity of new gas, the slowing-up of combustion because of dilution is demonstrated experimentally to be about proportional to the cube of the mass-dilution ratio.

The scientifically valuable part of the paper is the naming of the factors that affect the explosion-time of an engine, the giving of mathematical expressions for their laws of action and the finding of the numerical values of constants for such factors as turbulence and dilution. The measurement of the optimum spark-advance is made available as a research method for investigating the reaction rates of combustion, and hence of all that related group of topics now of interest to automotive engineers.

By measuring the optimum spark-advance, the combustion rates of gasoline with and without "anti-knock," or tetraethyl-lead, were measured. Although the quantity used was 20 times the normal amount, no change in the reaction rate of combustion was found when the combustion remained normal, that is, without detonation. When detonation occurred without anti-knock, the reaction times with anti-knock followed those to be expected with normal combustion. Detonation apparently changed the combustion habit as if it produced an abnormal top to the combustion.

IN the literature of automotive engineering there is little to be found about spark-advance. There is plenty of material about the electrical and mechanical design and the operation of apparatus for producing the ignition spark but the proper timing of the spark seems to be assumed. Ignition without timing control is comparable logically to a carbureter that will produce merely some kind of a fuel-air mixture without proportioning the mixture to the load and the speed of the engine.

It can be shown experimentally that the timing tolerance within which the spark must occur to get within 10 per cent of the best power and economy of the engine is about ± 20 deg. in a low-compression or 4 to 1 engine, and about ± 15 deg. in other engines. It may well be assumed that the average regulation of the spark by an ordinary driver of a car is not nearly as close as this.

The problem of spark-advance has two phases of importance: (*a*) finding whether the requirements of the optimum spark-advance at various combinations of load

[1] M.S.A.E.—Professor of experimental engineering, Cornell University, Ithaca, N. Y.

load speed are such as might be met by simple automatic mechanism, and (2) investigating scientifically the underlying theory of ignition governors. In the practical question the speed apparently is gas, optimum spark-advance has to be alternatively represented by additive functions, one of speed only, the other of load, or intake-suction, only; hence a simple mechanism can be made to cover both the load and the speed effects. The scientific investigation is of extreme interest, for it seems that determining the optimum spark-advance involves a direct measurement of the volumetric or the spacial flame-speed, and a study of the variation of the optimum spark-advance with the load or the intake suction, the speed and the mixture-ratio leads to a quantitative numerical evaluation of the reaction-rate of combustion, turbulence, dilution with spent gas, and the like; all of which make a very valuable auxiliary and independent check on such fundamental investigations as those recently published by Midgley and his associates.

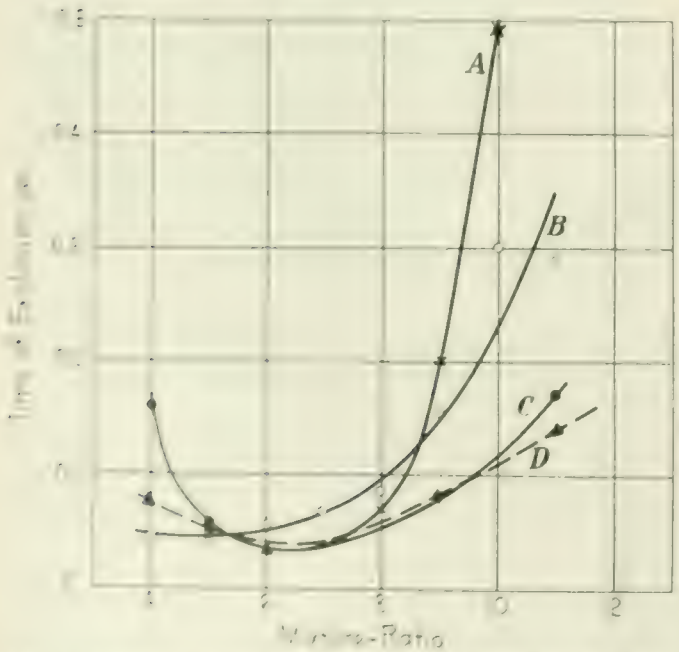
Review of Data

The first stage of an engineering investigation is a survey of extant scientific data. Next come the comparing and the correlating of such data with empirical practice. Good collections of data for our purpose are to be found in A. W. Judge's book, Automobile and Aircraft Engines, and in vol. 1, on Mechanics and Heat, of Glazebrook's Dictionary of Applied Physics.

Research on "explosions" in bombs brings out this essential that the explosion-time, or the time-duration of an explosion, is the time elapsing between ignition and the pressure peak, or the time of maximum pv product, if the volume is changing. The explosion-time is found to be

(1) Dependent on the mixture-ratio and the fuel used

(2) Independent of the absolute pressure, or the density, before ignition



(3) Somewhat dependent on the size and the shape of the explosion-chamber and the position of the ignition-point

(4) Greatly decreased by the turbulence of the mixture

The bomb experiments available in technical literature do not go into the effects on the duration of the explosion of two other variables, both of importance in an actual engine. These are

(1) Dilution of the charge with spent gases from previous explosions

(2) The temperature of the charge just before ignition

Experiments on an engine show that the mixture of maximum power for any given condition of speed and load is substantially identical with the mixture for the minimum value of the best spark-advance. Any richer or leaner mixture than that of maximum power needs more spark-advance than the maximum-power mixture. Except on a cold engine, however, the extra spark-advance for mixtures reasonably near to the maximum-power mixture is small; and this experimental fact makes it possible to eliminate the mixture-ratio variable from the general discussion, and to revert to it only as a minor factor in a complete solution of the problem of spark-advance.

Since the time-duration of the explosion is independent of the density of the charge, this possible variable disappears. The change of spark-advance required on account of throttling is not a consequence of the change of the charge density, but of the change of dilution with spent gas and of the temperature preceding the ignition. A high-compression engine, when compared with a similar low-compression engine, has a faster explosion, not by reason of a different density of the charge, but by reason of a different dilution of the charge and of a different temperature preceding the ignition.

The effects of the size and the shape of the explosion or the combustion-chamber and the position of the ignition-point and also of the mechanical and electrical lag in the ignition system, can be taken care of in a given engine by finding a characteristic or imaginary explosion-time for that combustion-chamber, as a bomb, for the fuel, the mixture and the temperature used but without any dilution or turbulence effects. The absence of turbulence corresponds, of course, to a zero engine-speed.

The effects of dilution and turbulence can readily be found by brake tests of the engine over a fair range of combinations of speed and load; the dilution can be measured from observations of the exhaust and the intake-manifold pressures and temperatures and a knowledge of the compression-ratio of the engine. The effect of the dilution with spent gases is to increase the characteristic explosion-time of the carburetion chamber by multiplying it by a factor fixed by the extent of the dilution. The effect of turbulence is to decrease the characteristic explosion-time by multiplying it by a simple inverse function of the engine speed. The actual explosion-time from ignition to the time of maximum pressure, or the pressure peak with the engine warmed-up to normal running conditions, can be given as the product of the three independent factors; (*a*) the "characteristic time" of the combustion-chamber as a bomb, (*b*) the dilution factor and (*c*) the turbulence or speed factor.

The actual explosion-time or the duration is simply related to the optimum angle of spark-advance and the rotation speed of the engine. If R is the speed of the engine in revolutions per minute, its angular speed is $360R/60 = 6R$ deg. per sec. When a is equal to the

angle of spark-advance, the timing of the spark ahead of the dead-center position of the engine, in seconds, is $a/6R$. It can be shown that for optimum spark-setting $a/6R = 3/4$ · the actual explosion-time = $3/4 \times$ the "characteristic time" $\times$ the dilution factor $\times$ the turbulence or speed factor. In this relation the characteristic time is a constant for a given engine and its ignition system under the ordinary operating conditions of the engine.

Explosion-Time

I shall review briefly the literature on explosion-time. Fig. 1 summarizes tests by various experimenters with mixtures of coal-gas and air. It will be seen that for mixture-ratios from 5.0 to 7.5 by volume, the explosion-time runs from 0.04 to 0.06 sec. with relatively minor effects on account of the size of the bomb, and none from the change of initial pressure or density. Fig. 2 shows

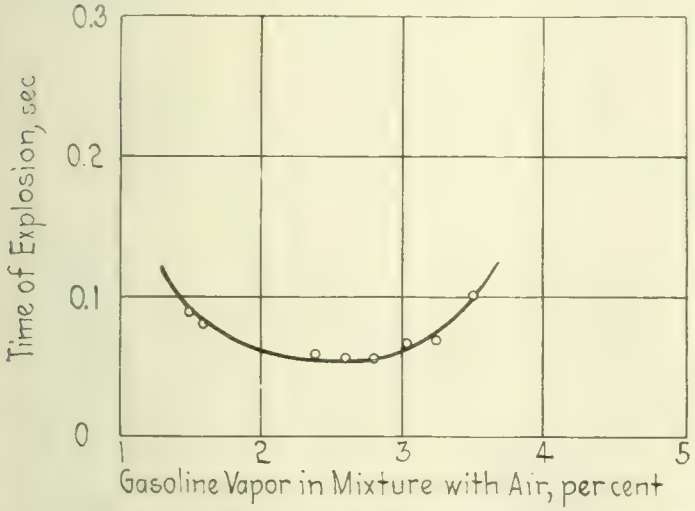


Fig. 2—Results of Experiment at Massachusetts Institute of Technology with a Gasoline Vapor-Air Mixture

from results obtained at the Massachusetts Institute of Technology that mixtures of gasoline vapor and air have the same characteristics as those of coal-gas and air; the minimum explosion-time in the bomb was 0.058 sec. In contrast to this explosion-time for gasoline in the bomb, Watson[2] gives the explosion-time in a racing-engine as 0.0055 sec. with single-spark ignition, and 0.0037 sec. with double-spark ignition. The speeding-up of the explosion in the engine, more than 10 times as compared with that of the bomb, is said to be due to the turbulence effect in the engine. Humphrey[3] found the explosion-time to be 0.026 sec. in a 28½ x 30-in. cylinder at 128 r.p.m.; Clark[3] found the explosion-time in a 9 x 17-in. cylinder at 180 r.p.m. to change from 0.033 sec. under normal operation to 0.080 and 0.090 sec. when the turbulence was allowed to die out before ignition.

Judge[4], by pressure-time diagrams, shows that the explosion-time in a certain engine was 0.013 sec. with gasoline as fuel, and 0.014 sec. with benzol. Comparing the data as to the explosion-times of various fuels[5] tested under like conditions, it seems that changing the fuel has a very small effect on the explosion-time. Alcohol, however, might be different from the hydrocarbon fuels,

[2] See Dictionary of Applied Physics, by R. Glazebrook, vol. 1, p. 299.

[3] See Dictionary of Applied Physics, by R. Glazebrook, vol. 1, p. 300.

[4] See Automobile and Aircraft Engines, by A. W. Judge, p. 30.

[5] See the curves of results obtained at the Massachusetts Institute of Technology with coal-gas and air in Fig. 1 and gasoline and air in Fig. 2.

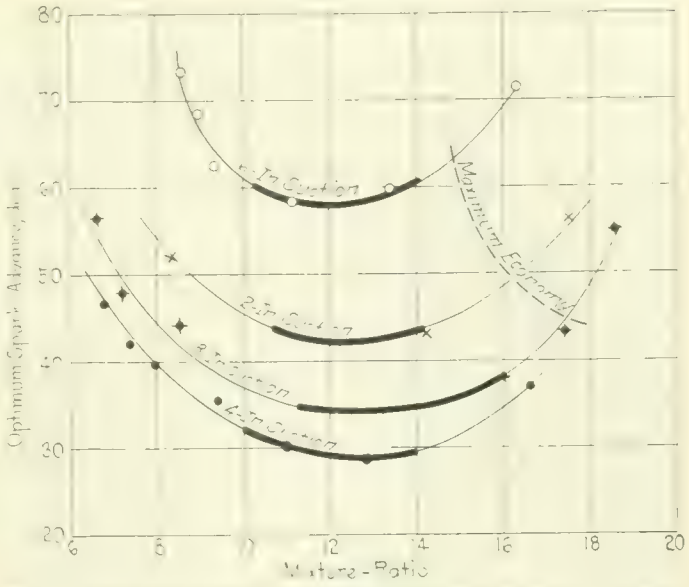


Fig. 3—Results of Optimum Spark-Advance Tests on a Ford Engine

which, having substantially the same explosion-times, could be substituted for one another in an engine without any appreciable change of the optimum spark-advance.

It will be noted that the curves of Fig. 1 of the explosion-time plotted against the mixture-ratio are fairly flat over a considerable range of mixture-ratios. This suggests that the optimum spark-advance in the practical operation of an engine may not be radically affected by the mixture-ratio. Tests on this point were first made by us on a Ford engine in the Cornell University laboratories with the results shown in Figs. 3 and 4. The airflow to the carbureter was measured by a Durley meter and box and the gasoline flow by a modified Pen-

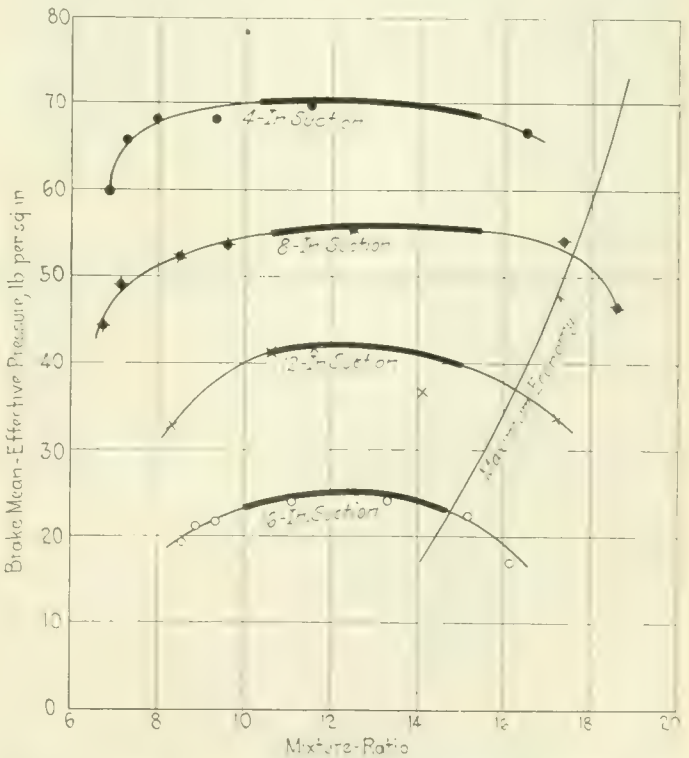


Fig. 4—Curves of the Brake Mean-Effective Pressure Developed by a Ford Engine at Various Mixture-Ratios

time of a 1 to 6 volumetric mixture of coal-gas and air was still 0.058 sec., the same, within the accuracy of measurement, as at the low pressures. The density of the charge, then, is not a factor in this problem. The same conclusion follows from Midgley and Janeway's recent paper on Laws Governing Gaseous Detonation. They found that mass rate of "burn" was proportional to the first power of the initial density. Since mass is volume times density, it follows that the volumetric or the space rate of flame travel is independent of the initial density. Engines of similar design but of different compression-ratios have different combustion rates, not because of the different densities at ignition, but because of the different temperatures preceding combustion and the different dilutions with dead gas, and perhaps because of differences in turbulence. Also, in throttling an engine the operative factor calling for more spark-advance is not a change of the density but a change of the dilution, and perhaps a change of the mixture-ratio received from the carbureter.

In Fig. 1 it will be seen that no systematic change in the explosion-time can be traced to a difference in the shape and the size of the bomb chamber used. The only bomb experiments quoted in Glazebrook or Judge that give data about the distance of flame-travel as affecting the explosion-time are those of Bairstow and Alexander[6]. In a cylindrical bomb, 10 in. in diameter by 18 in. long, they shifted the ignition-point by 3-in. steps from one end to the other. The explosion-time was the shortest with central ignition and the longest with end ignition. Their data are reasonably well fitted empirically by assuming that the explosion-time is proportional to the square root of the distance from the ignition-point to the more remote end of the bomb. The same square root of the distance for the time of flame travel also fits close to Watson's figures,[5] quoted above, of the explosion-time in a racing engine at 0.0055 sec. with single ignition, and 0.0037 sec. with double ignition. It seems probable that in an actual engine the shape of the combustion-chamber and the position of the spark-plug or plugs in it will be more important practically in determining the explosion-time than the absolute dimensions of the combustion-chamber.

Data on the effect of the initial temperature on the explosion-time in bomb experiments seem quite lacking. The best information seems to be given in Midgley and Janeway's paper[7] on the Laws Governing Gaseous Detonation, where it is found that the combustion rate varies approximately as the cube of the absolute temperature before ignition. For a given engine the rise of the temperature during compression is a definite multiple of the temperature at the beginning of compression; this in turn is fixed largely by the temperature of the air entering the carbureter. Hence, for a given engine the explosion-time and the spark-advance vary inversely, by some power higher than 1, as the absolute temperature of the entering air. In comparing one engine with another, since the rise of the temperature during compression varies with the y-1 power of the compression-ratio, and the combustion-rate varies with the cube of the absolute temperature preceding ignition, we shall have a combustion-rate varying as the compression-ratio to the $3(y\text{-}1)$ $= 3(1.33 - 1) = 1.0$ power; in other words, in engines similar but of different compression-ratios the optimum spark-advance should vary inversely as the compression-ratios.

The increase of the combustion-rate with the cube of the absolute temperature may well be the reason that, in constant-volume combustion, the combustion-rate in-

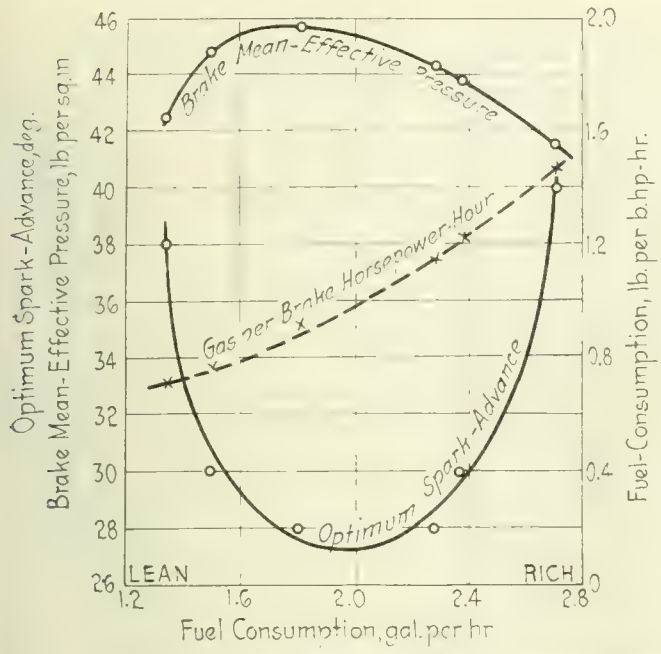


FIG. 5—OPTIMUM SPARK-ADVANCE AND BRAKE MEAN-EFFECTIVE PRESSURE CURVES FOR A CONTINENTAL SIX-CYLINDER ENGINE

creases as the combustion progresses. For the expansion of the first portions burned causes an adiabatic compression of the unburned residue and the consequent rise of the temperature ahead of the chemical reaction.

The lesser spark-advance that satisfies an engine, as it progresses from clean to dirty, or "carboned," in the combustion-chamber, is also largely a temperature effect. A dirty engine has less loss of heat to the walls of the combustion-chamber than has a clean one and a higher temperature of the charge at the end of compression; hence it needs a decreased spark-advance.

ANALYSIS OF SHAPE OF PRESSURE-TIME CURVES

The fact that the explosion-time varies as about the square root of the distance the flame has to travel suggests a simple line of attack on the analytical problem of the shape of the pressure-time curves of the explosions. In turn, the shape of the pressure-time curve determines what fraction of the explosion-time should come ahead of the dead-center position of the piston. This fraction of the explosion-time ahead of dead-center is the tying relation between the explosion-time and the optimum spark-advance. Too early ignition leads to losses through the compression of the burnt charge after combustion by the motion of the piston; losses partly from the excessive heat-transfer to the combustion-chamber walls, and partly from abnormally large dissociation effects stopping combustion. Too late ignition means that combustion is still going on appreciably as the expansion stroke begins, and hence leads into losses best understood from the thermodynamic theory that heat is less available for conversion into work when it is released at lower temperatures. Since the piston actually does move while combustion is going on, instead of being instantaneous as is postulated in the thermodynamic cycles in the textbooks, the actual timing of the combustion process in the engine cycle is a compromise between too early and too late and involves elements of both. Combustion should begin while the piston is moving up, and should end while the piston is moving down. Just where, with regard to the piston motion, should the combustion be timed for best efficiency?

If the time of flame travel in constant-volume combustion is proportional to the square root of the distance, the velocity of the flame travel will vary as the first power of the *time* from ignition. This is not in conflict with Midgley's calculations,[9] for he has been studying the combustion-rate as a function of the pressure and the temperature, not as a function of the time from ignition. Furthermore, flame velocity is actually a compound affair; the flame travel has two components, one of actual velocity with regard to the gas, and the other of the mass-motion of the gas itself. No attempt will be made in this paper to separate these two components of flame velocity with regard to the cylinder.

I have assumed a combustion-chamber of cylindrical form, with a height equal to one-third of its diameter, and with the ignition-point in one end, half-way from one side to the center. The time for a complete combustion, the explosion-time, I have taken as unity. The final velocity also has been taken as unity. With the velocity proportional to the time, the same decimal then stands for the time or for the velocity, in terms of their terminal values. The distance of the flame-front from the ignition-point varies as the square of the time from ignition. Up to about one-half of the time of complete combustion the flame-front makes a hemispherical surface about the ignition-point, the flame having not yet been cut-off by running into the combustion-chamber walls. In this first half of the combustion-time, therefore, the area of the flame-front varies as the square of the distance of the flame-front from the ignition-point and, in consequence, as the fourth power of the time from ignition, since the distance itself varies as the square of the time. The volumetric rate of combustion is the product of the velocity of the flame and the area of the flame-front; hence the volumetric rate of combustion varies as the fifth power of the time from ignition. The total volume or mass burnt is the time-integral of the volume rate of combustion, and the rise of pressure is proportional to the total volume or mass burnt up to a given time. Hence, we conclude that during the first half of a combustion that is started from a spark-plug

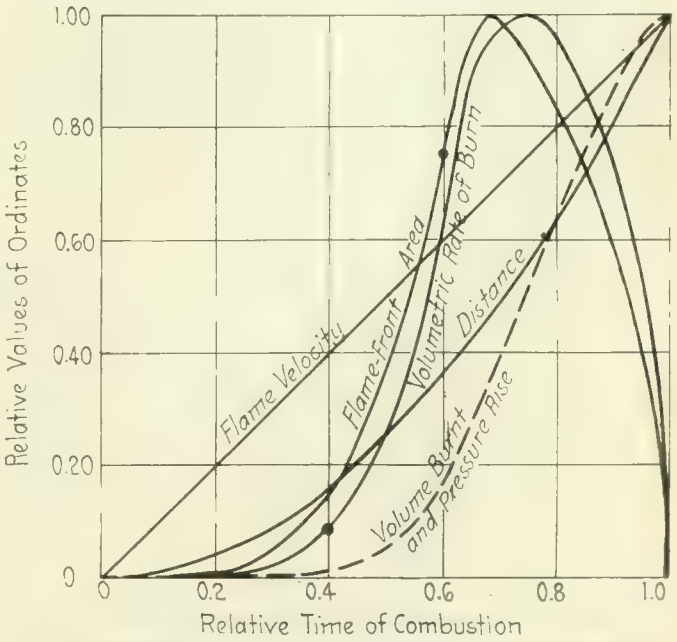


FIG. 6—THEORETICAL STUDY OF THE PROGRESS OF COMBUSTION IN A CYLINDRICAL COMBUSTION-CHAMBER

[9] See THE JOURNAL, April, 1923, p. 367.

[illegible] of pressure will vary approximately as the cube root of the time from ignition.

This is the explanation of the shape at the beginning of the pressure-time curves of combustions in either bombs or engine-cylinders. On such curves there appears to be an appreciable "lag" in time-interval, in which there is no perceptible rise of pressure. On a sixth-power law the pressure at the time $\frac{1}{2}$ is 1.64 of that at the time unity, a change easily noticed, relatively. Fig. 6 shows curves representing the mathematical relations outlined above.

At about one-half the time of a complete combustion the flame-front ceases to be hemispherical, being cut-off in part by running into the walls of the combustion-chamber. From this time on the flame-front begins to lose area, first slowly, then rapidly, and becomes zero as the combustion ends. The exact law of the change of flame-front area with position or time depends on the shape of the combustion-chamber and the position of the ignition point, what we may call the geometric lay-out in our case. For the simple combustion-chamber chosen and described I have worked out these flame-front areas for the last half of the combustion-time; and they are plotted in Fig. 6 with an arbitrary choice of a maximum area of flame-front equal to unity.

The product of the flame velocity and the flame-front area gives the volumetric rate of "burn." This continues to rise for a little while even after the flame-front area has begun to decrease, because the flame velocity is still increasing; but the decreasing area of the flame-front soon becomes the dominant factor, and the volumetric rate of burn must reduce to zero as the combustion ends.

The time integral of the volumetric rate of burn is the volume burnt and is proportional to the rise of the pressure from the combustion. This calculated curve of pressure-rise plotted against time in Fig. 6 is the end toward which we have been working. It is shown to be a direct consequence, in its form, of the law of flame velocity plotted against time and the geometry of the combustion-chamber. The velocity-time law chosen was the simplest possible; it remains to be seen whether the results deduced from it give a fair picture of the actual progress of combustion in bombs or engine cylinders.

We may summarize the results shown in Fig. 6 in a few numerical statements. According to these calculations the maximum area of the flame-front occurred at 68 per cent of the explosion-time, the maximum rate of burn at 74 per cent of the explosion-time, the beginning of the appreciable rise of pressure from combustion at between 40 and 50 per cent of the explosion-time and the half rise of pressure at 74 per cent of the explosion-time. The figures for the fractions of explosion-time at which the rise of pressure begins to be perceptible and at which it reaches half value are the important figures for our study.

Judge, in the chapter on Explosion and Combustion[1], gives a number of pressure-time cards from bombs and from engine cylinders. In Petavel's spherical bomb, the half pressure-rise came at 85 per cent of the explosion-time. In Hopkinson's bomb that was nearly spherical and had central ignition, the half pressure-rise came at 81 per cent of the explosion-time. In spherical bombs the reduction of the flame-front area by running into the walls would be expected later in the burn than in a cylindrical vessel; these figures are not inconsistent with the computed 74 per cent for a cylindrical chamber. One pressure-time card from a gasoline engine shows the half pressure-rise at 65 per cent of the explosion-time, while with another it is at 72 per cent; the same engine, with benzol, gives 69 per cent; a producer-gas engine gives 79 per cent for the half rise, and 44 per cent for the beginning of the rise.

To check the shape of the pressure-time curve in our own experiments we used a 7-hp. stationary Fairbanks hit-or-miss engine in the Cornell University laboratory. The speed of 340 r.p.m. made it possible to take indicator-cards with a Crosby indicator; the indicator-drum drive was offset 90 deg. so that pressure-time cards were obtained. In this engine we found the ratios to the total explosion-time for the beginning of the rise of pressure and for the half rise to be 0.54 and 0.81 on a lean mixture; on the maximum-power mixture, 0.54 and 0.77, and on a rich mixture, 0.44 and 0.71. Altogether, it seems that, for engines in general, we may assume pretty accurately that half pressure-rise will occur at, or very close to, 75 per cent of the explosion-time. The theoretical conclusions of Fig. 6 are confirmed experimentally, though the assumption as to the law of flame velocity was so inadequately simple.

Correlation of Optimum Spark-Advance and Explosion-Time

This brings us to the relation, or correlation, between the optimum spark-advance and the explosion-time. For we may reasonably assume that we wish to time the spark, for best results, so that the combustion will occur at one-half before and one-half after the dead-center position of the piston, or that the half pressure-rise will occur at the dead-center. This makes about the best approximation to a vertical combustion line on the pressure-

TABLE I—[illegible] OF PRESSURE-VOLUME AND PRESSURE-TIME INDICATOR CARDS OBTAINED FROM FAIRBANKS 7-HP. 3 & 7 IN. STATIONARY HIT-OR-MISS ENGINE, RUNNING AT 340 R.P.M.

Timing by Pressure-Time Cards	Timing by Spark Advance	Pressure-Time Cards; Timing, Deg. of Pressure-Rise: Begin	Half	Peak	Explosion-Time, Sec.	Ratio to Explosion-Time: Beginning of Pressure-Rise	Half Pressure-Rise
Late	[illegible]	−15	−25	−40	0.029	0.58	0.75
[illegible]	[illegible]	− 1	−14	−22	0.026	0.60	0.85
[illegible]	[illegible]	− 15	− 1	− 9	0.024	0.51	0.84
[illegible]	[illegible]	+ 29	+ 13	+ 3	0.023	0.45	0.79
Late	[illegible]	− 8	−20	−31	0.025	0.55	0.78
[illegible]	[illegible]	− 2	− 8	−23	0.026	0.53	0.72
Good +	[illegible]	− 11	− 1	− 9	0.024	0.59	0.80
[illegible]	[illegible]	+ 25	−19	+ 2	0.025	0.48	0.77
Late	[illegible]	− 15	− 25	−40	0.029	0.58	0.75
Good	[illegible]	− 1	− 12	−30	0.029	0.43	0.70
[illegible]	−40	− 15	− 1	−22	0.030	0.40	0.66
Late	[illegible]	+ 2	+ 1	−14	0.031	0.34	0.72

TABLE 2—AVERAGE RESULTS FROM FAIRBANKS ENGINE TESTS

Mixture	Explosion-Time, Sec.	Fraction of Explosion-Time Ignition to Beginning Pressure Begin	Fraction of Explosion-Time Ignition to Beginning Pressure Half	Actual Time, Sec.—Ignition to First-Half of Pressure-Rise	Actual Time, Sec.—Last-Half of Pressure-Rise
Lean	0.0255	0.54	0.81	0.0138	0.0048
Good	0.0250	0.54	0.77	0.0135	0.0058
Rich	0.0299	0.44	0.71	0.0132	0.0087
Average of all Mixtures	0.0268	0.52	0.76	0.1350	0.0070	0.0064

Calculated optimum spark-advance, for half pressure-rise exactly at dead-center; lean mixture, 42 deg.; good mixture, 39 deg., rich mixture, 43 deg.

volume indicator-card, and we know pretty well from practice that a nearly vertical combustion line in that card is indicative of the best power and efficiency of the engine.

To check the assumption that the timing of the spark so that the half pressure-rise will occur at the dead-center, or that the explosion-time will be three-quarters over at dead-center, for the best pressure-volume indicator-card shape, we made experiments on a 7-hp. Fairbanks stationary engine. Both pressure-volume and pressure-time indicator-cards were taken. The results are given in Table 1. The first column of the table gives the mixtures; the measurement was in turns of a needle-valve in a plain venturi carbureter. The second column gives the judgment as to the spark-timing from the shape of the pressure-volume indicator-card. Late timing is indicated by — signs and early timing by + signs; the measurements of the timing are in degrees of crankshaft rotation from the dead-center. The spark-advance was measured on a calibrated index-scale on the timer by jump-spark ignition. Particular attention is called to the correlation of the second column, the timing by the pressure-volume card with the fifth column, the timing of the half pressure-rise in crank-angle degrees. It will be seen that the cards called "good" in pressure-volume card shape had the half pressure-rise substantially at the dead-center.

Table 2 summarizes and averages the results of the tests in Table 1. Each result in Table 1 is itself the average of four or five cards of each kind, either of pressure-volume or of pressure-time. It is interesting to study, in Table 2, the change in the combustion habit with the mixture-ratio. The time from the ignition to the beginning of the pressure-rise seems to be independent of the mixture-ratio. The first half of the rise of pressure of the lean mixture is slow and the last half fast, as compared with the other mixtures. The rich mixture is slow in both halves of the pressure-rise but more so in the second half. The maximum-power mixture is not only the quickest to burn, but has a considerably more rapid and more symmetrical pressure-rise. The very high speed of burning in the last half of the pressure-rise of the lean mixture may be tied up with the fact that such mixtures are the only kind that backfire in an engine. The calculated optimum spark-advances for all three mixtures in Table 2 are astonishingly close, 42, 39 and 43 deg., and these results confirm our tests on the Ford and Continental engines very nicely. They also check the 40-deg. spark-advance data in Table 1 closely. The optimum spark-advance in Table 2 is calculated by converting the time in seconds for each mixture, from the ignition to the half pressure-rise, into crankshaft degrees ahead of the dead-center.

We may consider that we have proved experimentally what we deduced theoretically, that the optimum spark-advance is such that the half pressure-rise occurs at the dead-center; and that this stage of the pressure-rise occurs practically at 75 per cent of the explosion-time after ignition. Writing a for the spark-advance in degrees, and a_o for the optimum advance, e for the explosion-time, R for the number of revolutions per minute, we have then $a/6R$ = the spark-advance in seconds, and $a_o/6R = \frac{3}{4}e$ whence $a_o = 9eR/2$ and $e = 2a_o/9R$. By finding a_o for an engine on the test stand, through the change of the spark as a single variable, noting the torques resulting while the speed, the intake-suction, the temperatures and the like are held constant, we can measure e, the explosion-time, under the conditions of the test. So through the optimum spark-advance we can investigate changes of the explosion-time by mixture variation, dilution, turbulence and the like and open the door to a wide field of study of combustion processes in engines.

Turbulence

I have mentioned already that turbulence is a factor in speeding-up combustion, quoting some results in engine tests by Dugald Clerk. Hopkinson[11] experimented on turbulence with a fan inside a cylindrical bomb 12 in. in diameter. He used a 1 to 9 mixture by volume of coal-gas and air. The data of his tests are plotted in Fig. 7. Assuming, as a most simple relation, that the speed of the flame travel is a linear function of turbulence, we should have flame speed equals the size of the bomb divided by the explosion-time or $K\ (1 + bR)$, where K is the reciprocal of the explosion-time without turbulence, and R is the revolution speed that measures the turbulence. Fig. 7 shows that this simple equation is satisfactory for the bomb tests. Later, it will be shown that the same type of equation holds good for an engine; R is then the speed of the engine in revolutions per minute. The constant b we shall call the turbulence factor. For Hopkinson's fan and bomb, the constant b

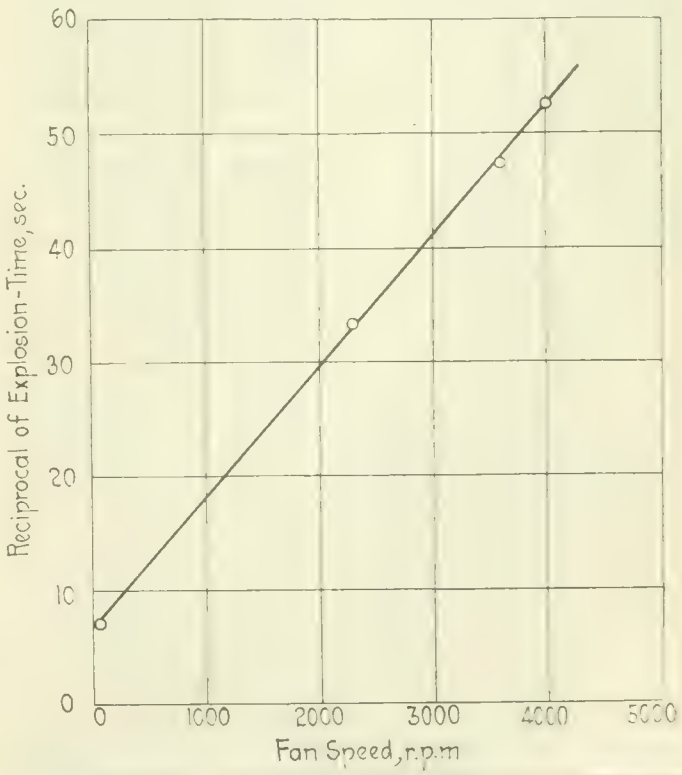


Fig. 7—Results of Hopkinson's Experiments with Turbulence from a Fan in a Bomb

[11] See Automobile and Aircraft Engines, by A. W. Judge, p. 55.

is 0.0015 in automotive engines [illegible] fractions of the general [illegible] of 0.001. This means that turbulence cuts the explosion time in two at 1000 r.p.m., divides it by 3 at 2000 r.p.m., and so on. In racing-engines the explosion time may be 1/5 and in engines with small cylinders that drop perhaps to 1/10.

In finding the turbulence factor for a given engine one must first eliminate from the results the dilution factor, the slowing up of combustion by dilution with exhaust gases that have been caught in the clearance space. The dilution at a constant speed increases as the throttle is closed, but is not zero at full throttle. After the dilution effect has been eliminated from the test results, the curve of the optimum spark-advance for zero dilution versus the speed can be analyzed for the turbulence factor after the manner of Fig. 7. Since e, the explosion time $= 2a - 9R$, the reciprocal of e is $9R - 2a_e$. A plot of $9R - 2a_e$ for zero dilution against R will find the constants $1/e_c$ where e_c is the characteristic explosion-time of the combustion-chamber of the engine as a bomb without turbulence or dilution, and b, the turbulence factor of the engine.

Dilution with Exhaust Gases

Dilution with exhaust gases is never absent in Otto-cycle engine operation. At the end of the exhaust stroke of a 4-stroke-cycle engine the clearance volume C of a cylinder is filled with exhaust gas at an absolute pressure of p_e and an absolute temperature of T_e. As the piston moves away on the suction stroke this exhaust gas, or the spent or dead gas, re-expands behind the piston. It continues to expand until the pressure drops to P_i, the intake-manifold pressure. Of course, when an engine with mechanically operated rather than automatic intake-valves is throttled, the exhaust gas flows from a cylinder into the intake-manifold when the intake-valve opens and is later sucked back through the valve into the cylinder. Essentially, however, the clearance gas must be expanded to the pressure P_i before any new charge enters the cylinder. The volume of the new charge taken per cycle at pressure P_i and temperature T_i is then $V + C$, displacement + clearance volume, less the volume of the re-expanded exhaust gas. This re-expanded volume is $C(p_e/P_i)^{1/\gamma}$; where γ is the ratio of the specific heats. The volume of the new gas per cycle is, then, at conditions P_i and T_i, $V + C - C(p_e/P_i)^{1/\gamma}$; the total volume, at the pressure is $V + C$. We may define the dilution ratio as the ratio of the total gas in the cylinder at the end of the suction stroke to the new charge. Volumetrically, the dilution ratio is $(V + C)/[V + C - C(p_e/P_i)^{1/\gamma}]$. If the compression-ratio is r $= (V + C)/C$, the volumetric-dilution ratio is $r/[r - (p_e/P_i)^{1/\gamma}]$. Those who deal with the mathematical analysis of internal-combustion engine operation will recognize in these expressions for the volumetric dilution ratio the reciprocal of the volumetric efficiency of the engine referred to intake-manifold conditions of pressure and temperature.

The manner in which the dilution with exhaust gas changes the combustion rate by slowing it is probably a complex of two things, each in its way a temperature effect. First, the exhaust or clearance gas is hotter than the fresh charge and as the two mix the temperature of the new charge is raised. This action does not disturb the volumetric calculations just given, because the expansion of one part of the gas by heating is counterbalanced by the contraction of another part by cooling. But the new charge, being hotter before ignition, might be expected to burn more rapidly because of the dilution. This does not happen, as it is swamped out and overcome by the second action of the dilution. This is the absorbing of the heat of combustion by the dead gases as the combustion progresses. The temperature to which the combustion would go if the gases were not diluted is greatly lowered by dilution. The operative factor is really the "heat-mass" of the diluting gases, their capacity for absorbing heat during the temperature rise, or the product of their actual masses by their specific-heats. As the new gas during combustion becomes exhaust gas, the specific-heats after combustion will be the same for the products from the new charge and for the products of a previous combustion that dilute the new charge. Hence, the dilution factor, which is operative in holding-down the combustion temperature, is simply the mass-dilution ratio of the total weight of the gas in the cylinder to the weight of the new charge. The heating of the new charge, previous to ignition, on account of its mixing with the diluting dead gases, is also nearly proportional to the mass-dilution ratio, the temperature being shifted from T_i toward T_e very nearly in the ratio of the masses of the old and of the new charges. This shift is affected somewhat by the fact that the specific-heats at temperatures T_i and T_e are not exactly the same; but the losses of heat to the cylinder walls during the suction and the compression strokes are much more important than any effect caused by the variation of the specific-heat with the temperature.

On the whole, then, we may expect the change in the combustion rate consequent on the dilution with dead gas to be some function probably of the mass-dilution ratio of the total gas to the new charge. And since the temperature effects are proportional to the mass-dilution ratio, and the temperature effects on the combustion rates can be represented fairly well by exponential functions, mathematically, we shall attempt to analyze the dilution effects by plotting the spark-advance versus the dilution ratios on logarithmic cross-section paper.

The volume $V + C - C(p_e/P_i)^{1/\gamma}$ of the new charge, at temperature T_i and pressure P_i is mixed with a volume $C(p_e/P_i)^{1/\gamma}$ of dead gas, of pressure P_i and temperature $T_e/(p_e/P_i)^{1/\gamma}$. Since the density of gases at the same pressure is inversely proportional to their absolute temperatures, the mass-dilution ratio of the total gas to the new charge is $1 + (p_e/P_i)\ (T_i/T_e)/[r - (p_e/P_i)^{1/\gamma}]$, an expression that may be compared with the corresponding one for the volumetric-dilution ratio.

In these expressions for volumetric or mass-dilution ratios the value of γ, the specific-heat ratio, was left unspecified. We may choose two cases to be tried out on test results. First, because of its simplicity, we may see what will happen if $\gamma = 1$, or the expansion is isothermal. Then the volumetric-dilution ratio becomes $1 + (p_e/P_i)\ (r - p_e/P_i)$; and the weight-dilution ratio becomes $1 + (p_e/P_i)\ (T_i/T_e)\ (r - p_e/P_i)$. The two expressions differ in this case only in the fact that the exhaust temperature is higher than the intake temperature. It follows that mass dilution is less than volumetric dilution under the same conditions.

There is another peculiar angle to this affair which is interesting. If T_e rises, at constant p_e and P_i, the cylinder gas does not get hotter, because the mass of the exhaust gases retained in the clearance drops as T_e increases in inverse proportion to T_e while its heat-content per unit mass increases in direct proportion to T_e. Hence, the heat added by the clearance gas to the new charge at constant p_e and P_i is fairly independent of T_e.

Actually we can hardly assume that the re-expansion

of the clearance gases is isothermal. If it is adiabatic, the value of y is around 1.30 to 1.35 and it will be convenient to take $1/y$ as 0.75. The analysis of the engine tests justifies this, as will soon be shown. Also, in determining mass dilution, T_e and T_i need to be measured while obtaining the experimental data.

In a wider field the change of the mixture-ratio may itself be taken as one kind of dilution. We may consider the perfect mixture, or the mixture for complete combustion, to be diluted either with excess fuel or with excess air. Actually this assumption is a rather poor one, in the case of rich mixtures at least, because the chemical reactions of combustion are not the same when the mixture-ratios are varied. But the nitrogen-component of the air probably acts as a diluent much as exhaust gas does in the engine. An inspection of the curves of explosion-time versus mixture-ratio, as in Figs. 1 and 2, shows a general tendency to a curve of cubic form, or thereabout, symmetrical about a vertex for the mixture at the maximum combustion-rate. It will be shown from the engine tests that combustion is slowed by dilution with exhaust gases in proportion to the inverse cube of the mass-dilution ratio.

In finding the dilution factor from engine tests one need not be particular about the value of p_e. At full load and speed, p_e may be appreciably higher than atmospheric pressure; but P_i is then close to atmospheric pressure, and dilution does not vary rapidly with p_e/P_i when this ratio is near unity. At light loads, p_e becomes substantially identical with atmospheric pressure; and P_i is equal to the atmospheric pressure less the intake suction. If P_a represents atmospheric pressure and S the intake suction, all pressures being in same units, of course, then p_e/P_i may be replaced by $P_a/(P_a - S)$ without much error. It is better, naturally, to measure values of p_e and P_i; but many extant data can be made available for fairly accurate determinations of dilution from the recorded values of S, with p_e unknown and P_a found by a reasonable guess.

Original Cornell University Tests

Our first tests to check the theory we have outlined, as affecting the optimum spark-advance for various loads and speeds, were made on a Ford engine in the Cornell

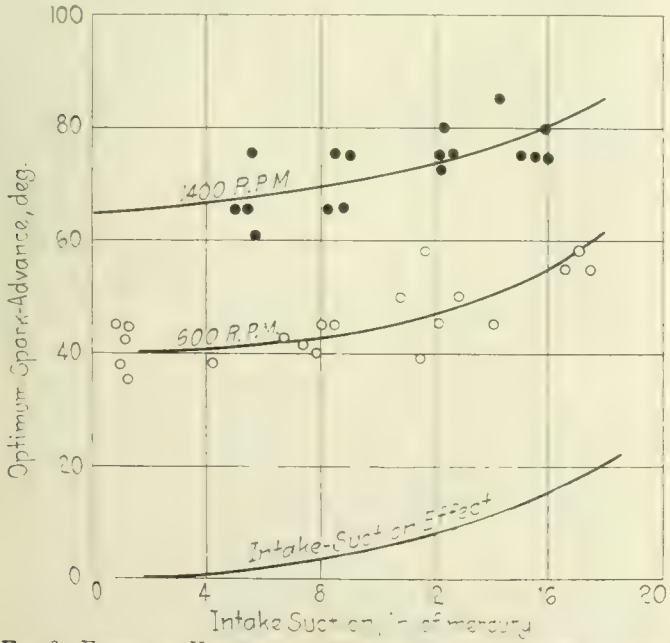


Fig. 8—Effect of Varying the Intake Suction on the Optimum Spark-Advance of a Ford Engine at a Constant Speed

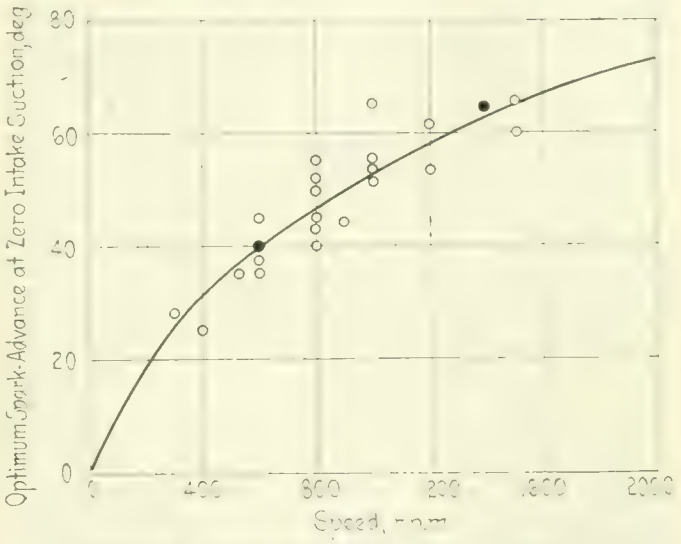


Fig. 9—Effect of Varying the Speed on the Optimum Spark-Advance of a Ford Engine

University laboratory. This is a stock engine with the exception of minor changes; it has Dow metal pistons, an Atwater Kent open-circuit ignition-system, and a Rayfield thermostat to control the temperature of the discharge water. The carbureter is of the regular Holley type. Instead of the air-horn for supplying heated intake-air we used electric heating, and the air was metered by a Durley orifice. The temperature of the entering air was kept at 140 deg. fahr. unless otherwise noted; the discharge water also was at 140 deg. fahr. A Froude water-brake was used to measure and absorb the torque. Gasoline was measured by a specially calibrated Penberthy flow-meter.

TABLE 3—OPTIMUM SPARK-ADVANCES ON FORD ENGINE

Speed R. P. M.	Intake Suction, In. of Mercury	Optimum Spark-Advance, Deg.	Tolerance in Spark-Advance for 10 Per Cent Power Loss
1,400	5.55	60	46 to 86
1,400	8.80	64	48 to 64
1,400	12.00	70	51 to 91
1,400	14.20	85	72 to 100
1,200	4.40	55	43 to 81
1,200	13.30	63	40 to 82
900	10.40	52	36 to 68
800	2.60	53	32 to 72
600	1.10	42	23 to 63
600	6.70	42	23 to 61
600	11.70	58	38 to 75
600	16.60	49	37 to 59

Some tests made on this engine, as a preliminary examination, have been presented already in Figs. 3 and 4. The determination of the optimum spark-advance was for some time a part of the students' work in the laboratory. Each day a series of combinations of load or intake suctions and speeds were investigated; at each load-speed setting a curve of the brake-torque versus the spark-advance with at least five points was found. Table 3 shows such a set of determinations in 1 day's work. These were obtained with the mixture always at or near the maximum-power value, the intake air and the discharge-water temperatures were 140 deg. fahr. and the barometric pressure was 29.35 in. After a considerable amount of data such as those in Table 3 had been collected, curves were plotted, as in Fig. 8, of the optimum spark-advance versus the intake suction for a constant speed. Such curves were used for reducing all the re-

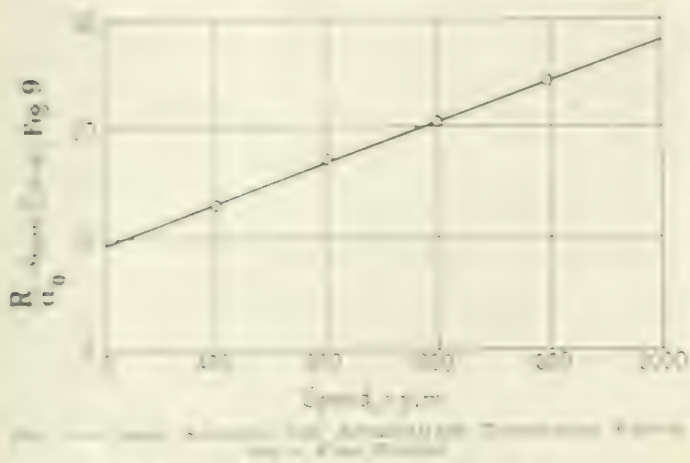
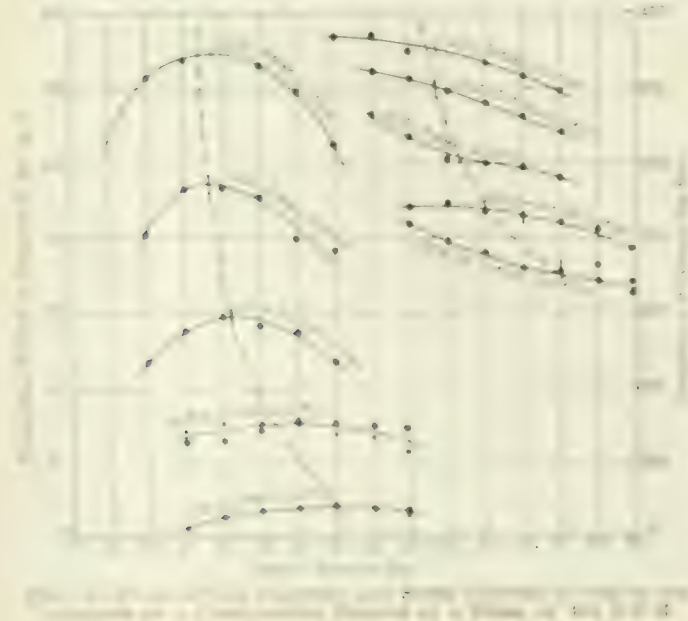


Fig. 9

suits to a zero intake-suction, as we had not at that time gone far in the analysis of the dilution effect. Reduction to a zero intake-suction is reduction to a constant, not zero, volumetric dilution with spent gas, and to a mass dilution that is not constant at all speeds, because the exhaust temperature rises with the speed. The curves of Figs. 8 and 9 will illustrate, however, a very good method of analysis for commercial purposes. In Fig. 8 the effect of intake suction is seen to be, with sufficient accuracy, the same for all speeds; in other words, a curve of intake-suction effect can be drawn at the bottom of Fig. 8, and a curve parallel to this will answer for each speed. With the aid of this curve for intake-suction effect all the data were reduced to values for a zero intake-suction, and with these reduced values the curve of the optimum spark-advance for zero intake-suction versus speed in Fig. 9 is plotted. The optimum spark-advance for any combination of speed and intake-suction can then be found by adding together the advance-for-speed effect from Fig. 9, and for intake-suction effect from Fig. 8. For example, at 800 r.p.m. a 12-in. suction requires 47 deg. for speed and 13 deg. for suction or a total of 60 deg.

It is obvious that if this possibility of representing the optimum spark-advance in a given engine as a sum of two parts, one for speed and one for intake suction, is confirmed on other engines, we have a basis immediately for an automatic mechanical control of the spark-advance



that will keep it always very close to the optimum value. In the example just cited, the control for speed alone would have to be set for the full-load conditions, and if the automatic control by speed alone were not corrected by supplementary hand-control the error of spark-setting at the 12-in. suction would be sufficient to cause a loss of about 5 per cent in power and economy. As this loss occurs under the most common running conditions, it is worth thinking about.

Since we have not, in the curve of Fig. 9, entirely eliminated the effect of dilution, but have merely reduced it to a point where the dilution effect is nearly constant, we cannot, perhaps, determine the turbulence effect with complete accuracy. The form of the curve in Fig. 9 is due principally, however, to turbulence effect. Hence, in Fig. 10, we plot $R\,a_o$ versus R, picking values of a_o from Fig. 9 for various values

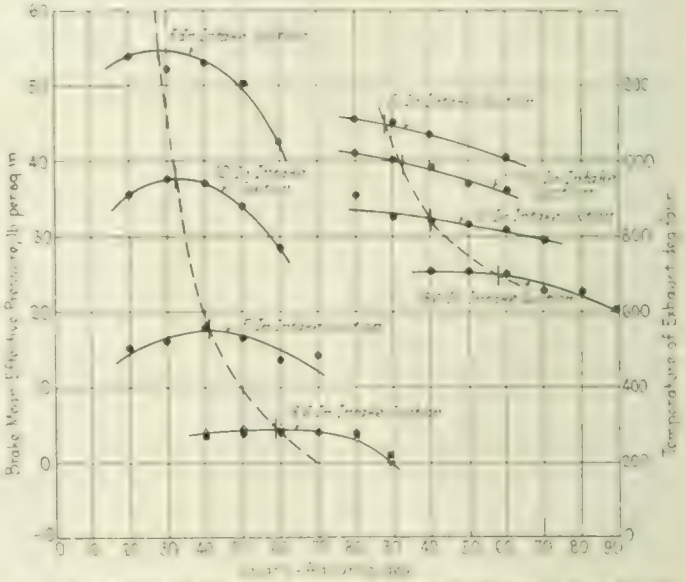


Fig. 12—Study of the Dilution and Speed Factors in the Spark-Advance of a Continental Engine at a Speed of 800 R.P.M.

of R. The curve in Fig. 10 is really only a graphic analysis of Fig. 9. The equation of the straight line in Fig. 10 is $R/a_o = 9.3\ (1 + 0.0010R)$ Hence the equation of the curve in Fig. 9 is $a_o = 0.108R\ (1 + 0.0010R)$. Since $a_o = (2/9)R$ times the explosion-time, it follows that the explosion-time of the Ford engine combustion-chamber as a bomb, without turbulence, but with the dilution corresponding to a zero intake-suction, is $(2/9) \times 0.108 = 0.0230$ sec.

It is rather gratifying to find, in Fig. 10, that turbulence in an engine corresponds to the same type of law of action as in the case of Hopkinson's bomb tests, as is shown by comparing Figs. 7 and 10; and that the turbulence factor for the speeding-up of the combustion by turbulence can be evaluated so readily by simple tests for determining the optimum spark-advance.

Supplementary Tests on a Continental Engine

As Fig. 8 shows, the data obtained from student work on the Ford engine were not good enough to evaluate the dilution factor in spark-advance in a scientific way. Hence, we turned to a Continental 7-R six-cylinder engine, which we have set up in the Cornell University laboratory, with an electric dynamometer and a fairly complete outfit of measuring devices. A Sylphon thermostat maintains the discharge water at from 135 to 140 deg. fahr.; the carbureter is of Stromberg make, model M1; the intake air is at room temperature, and a large

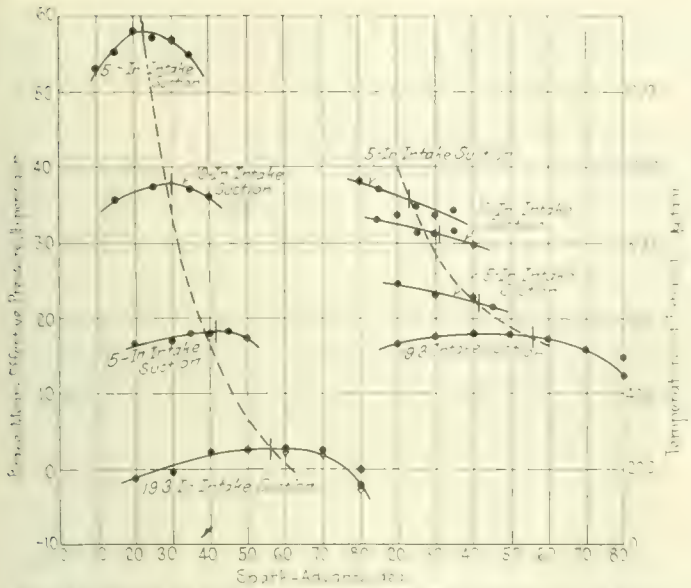


FIG. 13—STUDY OF THE DILUTION AND SPEED FACTORS IN THE SPARK-ADVANCE OF A CONTINENTAL ENGINE AT A SPEED OF 1200 R.P.M.

hot-spot incorporated into the manifold. The compression ratio is 4.55 to 1. At full throttle, this engine detonates considerably on Standard Oil gasoline and this fact was bothersome at times, yet led to one of our most interesting discoveries concerning the reaction-rate of combustion, or the effect of an anti-knock.

The main body of our experimental work on the Continental engine is shown in Figs. 11, 12, 13, and 14. At each of the speeds, 400, 800, 1200, and 1600 r.p.m., we

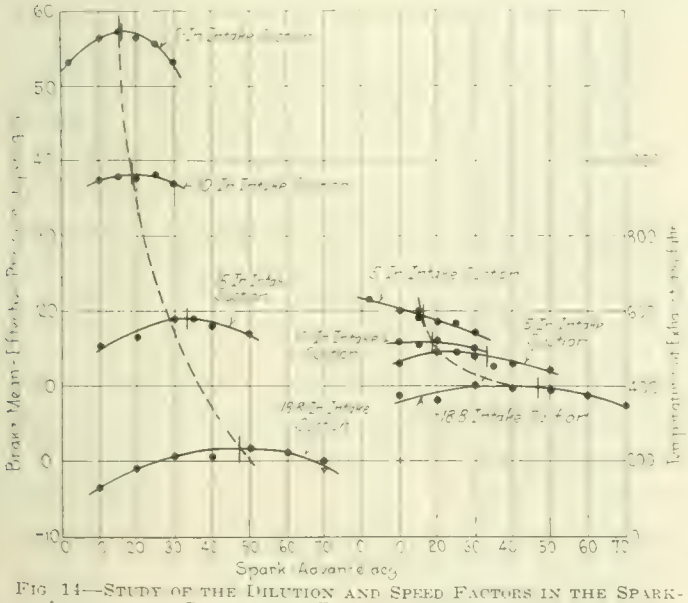


FIG. 14—STUDY OF THE DILUTION AND SPEED FACTORS IN THE SPARK-ADVANCE OF A CONTINENTAL ENGINE AT A SPEED OF 1600 R.P.M.

made sets of runs with the intake-suction at 5, 10, 15 and approximately 20 in. of mercury. In these runs we found the brake mean-effective pressure and the exhaust temperature as functions of the spark-advance. The optimum spark-advance can then be read off at the peak point of the brake-torque—mean-effective-pressure curve found for each combination of speed and suction resulting from a change of the spark-advance. Fairing curves represented by the dashed lines of Figs. 11 to 14 of the spark-advance versus the mean-effective pressure were then drawn in for each constant speed. The general results of varying the optimum spark-advance with the intake-suction or load are grouped in Fig. 15 and plotted for constant speeds. The observed points plotted in Fig. 15 are the peaks of the curves of Figs. 11 to 14, without fairing; the curves drawn in Fig. 15 are laid in with regard both to each other and to the fairing curves in Figs. 11 to 14. The curves of Fig. 15 are replotted in Fig. 16 as curves of the spark-advance at a constant intake-suction versus the speed.

Throughout the tests on the Continental engine the mixture-ratio was kept near to that of maximum power. When running near to the 20-in. suction any setting of the mixture for steady satisfactory running at the lower speeds was difficult and sometimes almost impossible; it could be done at the higher speeds. This circumstance

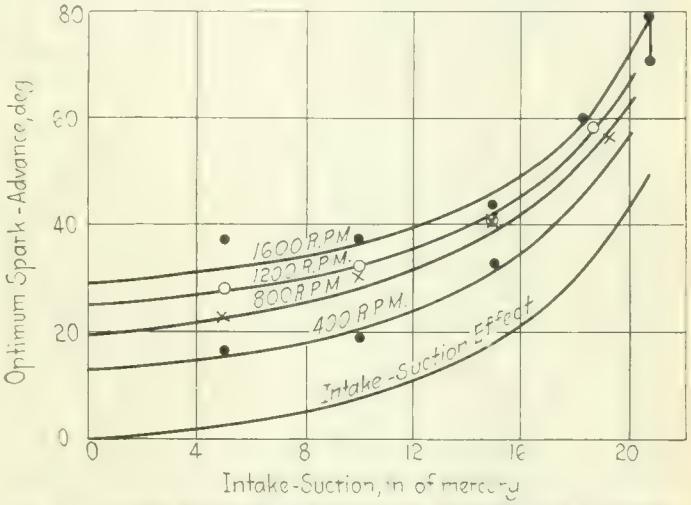


FIG. 15—CURVES SHOWING THE RELATION BETWEEN THE OPTIMUM-SPARK-ADVANCE AND THE INTAKE SUCTION FOR VARIOUS SPEEDS OF A SIX-CYLINDER CONTINENTAL ENGINE

probably is part of the reason that the spark-advance at the 20-in. suction must be so great at low speeds. The dilution of the charge with exhaust gas is, of course, very high at a 20-in. intake-suction; and it is higher at low speeds than at high ones, because the exhaust temperatures are higher at high speeds.

The exhaust temperatures found are plotted in Fig. 17 against the intake suction for constant speeds, and in Fig. 18 against the speed for constant intake-suctions.

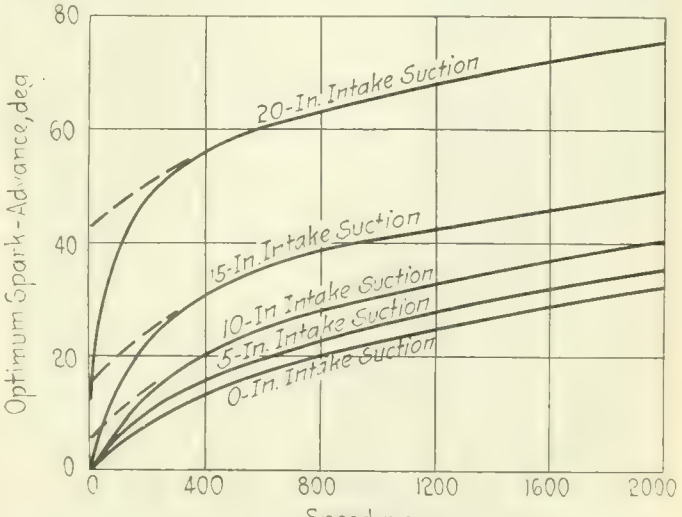


FIG. 16—CURVES SHOWING THE RELATION BETWEEN THE OPTIMUM SPARK-ADVANCE AND THE SPEED OF A CONTINENTAL ENGINE FOR VARIOUS INTAKE-SUCTIONS

(*Concluded on p.* 172)

The Coordination of Motor-Truck and Railroad Transportation

By W. J. L. Brosnan[1]

Cleveland Transportation Dinner Address

TRANSPORTATION is the most important problem in the Country today. The lack of transportation is seriously impeding the production of the Country and unless we can create a condition whereby it will be entirely possible to move a substantially increased tonnage by the more intensive use of our present facilities, the present unsatisfactory condition will continue and the public will be required to pay high freight-rates and in return receive unsatisfactory service.

The settlement of most transportation problems of national and general concern depends largely on the understanding of them and on the realization that the interests of the carriers, the shippers and the public are for the most part identical. Notwithstanding the phenomenal increase in transportation by motor truck, there is an insistent public demand for more and better transportation by rail. With hardly an exception, the main lines of the railroads in the United States have sufficient capacity for the moving of all freight that can be offered to them and, generally speaking, rail transportation is restricted only by the complicated movements and delay of cars and freight within the terminal areas.

The congestion at the railroad terminals, while resulting in the use of motor trucks, as supplements to railroad service within terminal areas, has opened up a field for their operation in competition with the railroads and has developed the use of motor trucks to furnish complete transportation between industries separated by what is deemed to be a reasonable trucking distance. The limit of a reasonable trucking distance is variously estimated. During the last 10 years, owners of trucks have undertaken to extend the limit to so-called long-distance trucking often with disastrous financial results to themselves, and their operations have aroused public clamor because of the damage alleged to have been caused by the movement of heavily laden trucks over highways, many of which have been recently constructed or improved at great public expense. The railroads also are feeling the effect of the competition of these long-distance trucking operations, paralleling railroad lines.

Considered within trucking areas and within a radius of 50 miles from the center of a terminal area, complete transportation of merchandise and of all other classes of freight can be furnished by motor trucks more efficiently and economically than by railroad. In fact, such transportation by motor truck is profitable, whereas the rail carriage involved it is unprofitable. It would therefore seem that if the motor truck and the rail carriage can be coordinated the activities of the motor trucks should be largely confined to the moving of freight within the terminal areas or adjacent thereto.

The public is entitled to the prompt movement of freight, and the carriers were performing this service, predicated on rail and transportation rates. There are three kinds of transportation agencies, railroads, waterways and highways. The public is entitled to that form of transportation which is most economical and should not be compelled to use any form of transportation that does not perform the service, from both a time and rate standpoint, to which it is entitled.

It is generally agreed that the highways and the motor trucks have been developed along most efficient lines, but the problem that has to do with the use of the highways by motor trucks still remains unsolved. This is due probably to the fact that there does not seem to be the proper relation between the highway and the rail carriers. This may be due to a lack of understanding as to the economic rights, in the interests of the public, of these two important forms of transportation.

The railroads of the Country are faced today with the most severe motor-truck competition covering short-haul freight movements, that tends to deplete further their much needed freight revenues. The motor truck is also hauling freight long distances, frequently at rates that are considerably higher than rail rates, and if inquiry be made as to why the motor truck handles long-haul freight the answer usually is: The motor truck gives the service, while the railroads do not.

This is not entirely true, but it is true in a great many instances. Rail carriers complain that motor trucks haul freight when the rates are high and the road conditions are good. When motor-truck conditions are not favorable, particularly in winter, the railroads are required to haul this class of freight, which further adds to their many transportation troubles.

It has been said that the public ultimately will define the economic range of the motor truck. This is undoubtedly true, but the public will have to be educated, either by the railroads or by the shippers, in order that they can arrive at the proper conclusion.

The highways and the motor truck can do much to help or hamper the rail carriers, but before improvement can be made it will be necessary to coordinate the rail and the highway and place each form of transportation in its proper economic field. It will, therefore, seem important that in the interest of the public the rail and the highway carriers should get together and endeavor to arrive at a proper understanding as to their rights.

The shipping public is being urged by the carriers to load cars to capacity and to unload and load promptly, which would mean the use of much additional equipment now idle, due to conditions over which the carriers do not seem to have control. There is a limit, however, as to the amount of freight that can be loaded on cars, which is controlled in a great many instances by commercial conditions. This is not true, however, so far as the prompt unloading and loading of cars is concerned. The carriers urge that this be done but make no recommendations as to how it can be accomplished. I shall therefore call to your attention the necessity for the closest cooperation between all parties in the interest of some method that would tend to speed up what we might call "terminal

transportation." This applies particularly to less-than-carload freight.

Terminal Transportation

The prevailing practice is to unload less-than-carload freight from cars into the freight-houses and to place carload freight on delivery tracks and then notify the consignee by mail of the arrival of the goods. Less-than-carload shipments remain in the freight-houses of the railroads an average time of 3 days; carload shipments remain on delivery tracks in excess of 2 days. A well-organized store-door delivery plan should make the freight-house space available for use not less than twice a day, instead of once every 3 days; thus the capacity of these facilities would be increased six-fold. The capacity of the delivery tracks should, under the store-door delivery plan, be increased four-fold.

The investment in freight-house and delivery-track space represents an item of expense that is frequently lost sight of by the railroads in their computation of the cost incident to the handling of the traffic involving the use of these facilities. Attention is, therefore, directed to the fact that this item alone, in some localities, represents an expense of $3 per ton on less-than-carload traffic and as much as $10 per day per car on carload traffic.

Obviously, therefore, an increase in the capacity of an existing facility results in a reduction in the overhead expense of operating the facility, provided that the increase in the capacity is utilized. With a reduction in the overhead expense and a substantial reduction in the labor cost of handling freight through freight-houses, the railroads could well afford to offer the consignee, as an inducement to avail himself of store-door delivery service, a rate that is substantially lower than he is now paying. Unless the plan is made attractive to the consignee the volume of traffic influenced by it will not be sufficient to afford the freight-houses and the delivery tracks any material relief. And by making available to the consignee a better service at a lower cost to him all grounds for criticism and objection would be removed.

If we are to speed-up the movement of the freight passing through the terminals it will be necessary for the carriers and the shippers to agree upon and develop a system of store-door delivery and collection service. This would mean the more intensive use of the present terminal facilities and would make it entirely possible to handle a heavier tonnage both inbound and outbound. It is important that the rail carriers have control of their freight terminals in order that they may clear them promptly of inbound and outbound freight, which does not seem to be possible under the present method of handling freight moving over the carriers' platforms and freight terminals.

What is needed at present is closer cooperation between the shippers and the receivers of freight and the rail carriers. The lack, however, of a definite plan for handling this class of freight has resulted in the freight's remaining in the carriers' terminals to the extent that there is more or less freight congestion at all times. When the congestion becomes acute, freight embargoes are issued by the carriers, that result in the partial stopping of freight movement until the terminals can be cleared. It further results in delaying the carriers' equipment, which is needed both at this and at all times.

The present cost of handling freight through the terminals warrants the carriers in taking all the steps possible toward the prompt removal of freight from their terminals. No storage charge is sufficient to reimburse the carriers for the freight held in their terminals, on account of the space occupied, the extra labor required through the consequent congestion and the cost of shipments lost or damaged by storage and congestion.

Can the motor truck be used to relieve freight congestion, thereby reducing the carriers' terminal expense, and to transport freight to and from the carriers' terminals to a greater extent than it is being used at present? Under a proper system and organization the motor truck should play an important part in speeding-up terminal transportation. To do this, however, it would be necessary for the carriers and the shippers to agree upon a store-door collection and delivery service, which seems to be the only method whereby freight can be moved to and from freight terminals in the shortest possible time. Store-door delivery would relieve freight congestion and delay, and should finally solve the carriers' terminal problem.

Practice in Canada

Canada has solved the terminal-congestion problem by the adoption of store-door delivery. Practically since the inception of railroads in eastern Canada carriers in the principal distributing centers have provided a cartage service to and from the freight terminals and the warehouses or the store-doors of the shippers and the consignees. Both services appear to be economically sound, even when viewed from the standpoint of the carriers' interest.

It is interesting to note the reasonable teaming charges in Canada, which are made possible by organized teaming under a store-door delivery system. The average cartage-rate on carload lots is $0.04 per 100 lb. and the average cartage-rate on less-than-carload lots is less than $0.06 per 100 lb., which covers delivery to the wholesale and the manufacturing districts, a radius of approximately 2½ miles from the terminals. The same cartage-rates prevail on outbound shipments moving from the shippers' warehouses to the carriers' terminals.

As already stated, the service in eastern Canada is governed by tariffs issued by the carriers and applies to practically all traffic coming under the generally accepted terms of merchandise and package freight. It contains many advantages to the carriers, the shippers and the consignees. With the exception of such consignees as have elected to do their own teaming and have so notified the carriers, no advice of arrival is given. The freight is billed to the teaming companies with charges to collect and is delivered from the terminal, or car if a carload, within a few hours of the unloading or the placing of the car on the team track. The teaming companies have their own superintendent in the freight terminal, whose business it is to see that the trucks are promptly dispatched with loads for delivery within certain areas or zones, with the result that freight usually is in the consignee's warehouse before an arrival notice could reach him by mail. All freight is moved through the carriers' terminals or from the cars with a minimum of delay and freight charges, and the receipt for the delivery of the freight is obtained from the consignees by the teaming companies.

The same principle governs outbound shipments. The shipper telephones the teaming company operating for the carrier over whose line he desires to ship that he has a load or half a load as the case may be. These orders are consolidated by the teaming company serving the district in question, the freight is picked up at the shipper's warehouse and the bill of lading is signed by the teaming company as agent for the carrier. It is then in transit, the carrier's responsibility under the system beginning at the shipper's warehouse door on outbound traffic and ending at the consignee's warehouse or store door on in-

one large terminal center, while at another terminal center when the traffic is handled by automotive equipment, 95 per cent of the freight so handled is delivered to the forwarding line on the same day that it is unloaded from the cars by the receiving line.

In some cases railroads have built substations outside the congested district, where all less-than-carload freight is concentrated, unloaded and reloaded into cars for distribution to various points. It is believed that, instead of reloading this freight into cars, it should be handled by automotive equipment, even though that service should prove slightly more expensive than moving the cars, to the end that relief may be afforded to the terminals and the cars be released for more profitable service. Unquestionably, prohibiting the use of cars and terminals for this character of service would measurably increase the capacity of the existing facilities.

The remedy for this situation presents no serious obstacles. It is only necessary for the railroads to arrange for handling the traffic by truck or dray. This arrangement might well be left in the hands of the local representatives of the railroads and the responsibility for the prompt and economical moving of the traffic be placed on them. If it should be found that no local transfer-company is equipped to do the work, it would be time to negotiate with an organization that is rendering a satisfactory and economical service at some other point.

The transferring of less-than-carload inter-line freight is also a costly operation to the carriers and tends further to congest the carriers' yards and terminals on account of delayed equipment, and with the methods now used in loading and unloading inter-line freight it seems that the motor truck is especially adapted for moving this class of freight, by the use of demountable bodies and other automotive equipment. I am firmly of the opinion that the result would be a speeding-up of inter-line freight and that handling by automotive equipment would result in profitable operation for the motor-truck companies and give prompt service to the public instead of delayed service and at a decreased cost to the rail carriers.

Trap Cars

The movement of less-than-carload freight now being handled in trap cars is a problem that still remains unsolved, and I am satisfied that when full consideration has been given to the rights of the highways and the motor trucks, without interfering with the just rights of the rail carriers, the motor truck can and should be used for this special class of service.

What has been said with respect to the use of cars and terminal facilities for handling interchange less-than-carload freight between railroads will apply with equal force to "trap-car" service. The term "trap-car" is used to designate a service that is performed free-of-charge by the railroads for the shipper or the consignee with track location, on less-than-carload shipments weighing, or aggregating in weight, 8000 lb. or more. The practice is recognized by railroad officers as an unprofitable one and its discontinuance has been proposed by them on several occasions, not only because of its unprofitableness, but also because it gives to the shipper, or the consignee, located on a track, free store-door service on less-than-carload freight, an advantage not enjoyed by shippers or consignees without track location. Freight agents and terminal superintendents are almost unanimous in expressing opposition to the handling of less-than-carload freight in trap cars. Their opposition is based on the

(Concluded on p. 138)

Air-Cooled Automotive Engines

By C. P. Grimes[1]

Metropolitan Section Paper *Illustrated with* Photographs and Drawings

THE author believes that the universal power unit will be direct air-cooled, but states that the direct air-cooled engine is now in the minority because, until very recently, there has not been a sufficiently broad series of established engineering facts and development work available to form a foundation for improvement. The satisfactory air-cooling of an 8 x 10-in. cylinder has been reported, and the development in a smaller cylinder of 138 lb. per sq. in. brake mean-effective pressure; also, in a three-cylinder, air-cooled, radial-engine, a brake mean-effective pressure of more than 125 lb. per sq. in. was developed and the engine endured beyond the ordinary expectations for water-cooled engines. Since these sizes and values are larger and greater than those of standard automobile engines, even though these developments may have been accomplished through the use of high-grade airplane-fuel, delicate aluminum finning and costly cylinder construction, the author feels justified in the conviction that direct air-cooling already is a success. The paper is devoted to a detailed and illustrated description and discussion of the engineering features of the car built by the company represented by the author.

THE direct air-cooled engine already has been developed to a state of perfection that should, in a very short time, allow it to prove the superiority of direct air-cooling. When constructed properly from recent designs it will be found that its exhaust-valves will be cooler, the carbon formation less and that it will be free from burnt and warped valves that so often are caused by the formation of a lime deposit in the water-jacket adjacent to the cylinder-head and the valve-seats. The universal power unit will be direct air-cooled because it already has been proved superior in the desert and for polar-expedition usage.

At present, the direct air-cooled engine is in the minority because, until very recently, a sufficiently broad series of established engineering facts and development work was not available to form a foundation from which the air-cooled engine successes of the immediate future could spring. S. D. Heron reports the satisfactory cooling of an 8 x 10-in. cylinder and the development in a smaller cylinder of 138 lb. per sq. in. brake mean-effective pressure, which is decidedly more than that developed by any standard automobile engine. C. Lawrance's three-cylinder radial-engine endured far beyond the expectation for any water-cooled engine and showed a brake mean-effective pressure of more than 125 lb. per sq. in. which, once again, is far higher than that used by any standard automobile engine. Although the above developments may have been accomplished through the use of airplane fuel, a delicate aluminum finning and costly cylinder construction, I feel confident that the results should warrant the conviction of the most skeptical that direct air-cooling is a success and must be recognized as such if further successful engine development is accomplished.

Cooling Ability

About 22 years ago, John W. Wilkinson applied his skill to the construction and operation of the first direct air-cooled car built by our company, and his work has resulted in our Series-10 car.

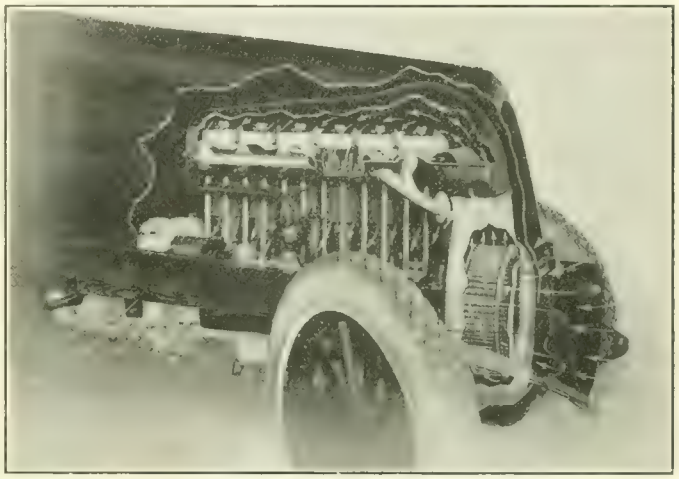
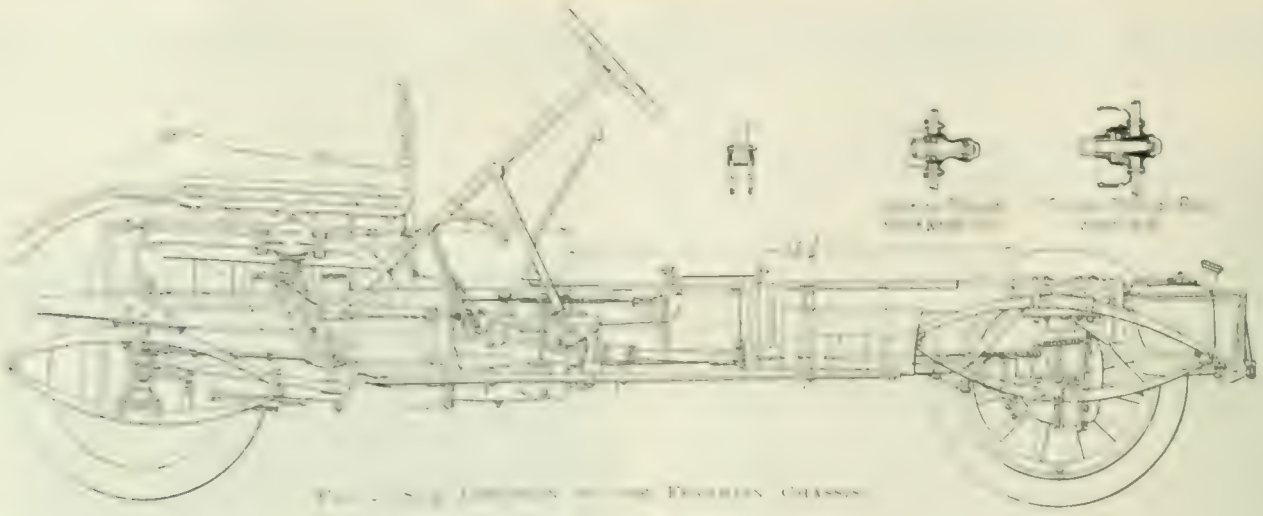


Fig. 1 Phantom View of the Cooling System Used in the Franklin Car

I acknowledge that the cooling system on some of the early models of our cars was not all that could be desired, but I believe the Series-10 cooling system to be at least the equal of any water-cooled system. Supposing a temperature of 100 deg. fahr. in the shade to be that of a summer day, that the powerplant of a Series-10 car, with all the gasoline tanks, the mufflers and the like, has been removed and mounted on a power jack to run a dynamometer or pump that will allow regulation of the load and that a stream of air or water is provided to play on the oil-pan; this engine can then be run with open throttle at a speed of 500 to 2500 r.p.m. as long as desired, without the necessity of using any additional air-cooling, I suggest that if the powerplant from a water-cooled car were tested in this same way, respect for the air-cooled engine would not be lessened. The Series-10 direct air-cooled powerplant has been operated from the Atlantic to the Pacific, far north and far south, through Death Valley and across the American Desert, and has demonstrated that the direct air-cooled engine has arrived.

Fig. 1 is a phantom view of the cooling system. The Series-9 engine used a Sirocco cooling fan 17 in. in diameter, of 3½-in. width of face and having 64 blades mounted on the flywheel to suck the cooling air down past the cooling fins, but the Series-10 fan is mounted at the front end of the crankshaft and blows the cooling air up through a duct over the top of the cylinder and then down past the cooling fins, exhausting into the hood of the car. The Series-10 Sirocco fan is 14 in. in diameter, has a 3½ in. width of face and 64 blades tipped 32 deg. forward the same as in the Series-9 engine. The blower system has been developed into a very efficient one that now delivers a greater volume of cooling air at a greater pressure, and yet consumes far less power to drive it, than does the Series-9 system, with the 17-in. fan. At 1600 r.p.m. of the engine, the 14-in. fan consumes 1 hp., as compared with 2 hp. for the 17-in. fan.

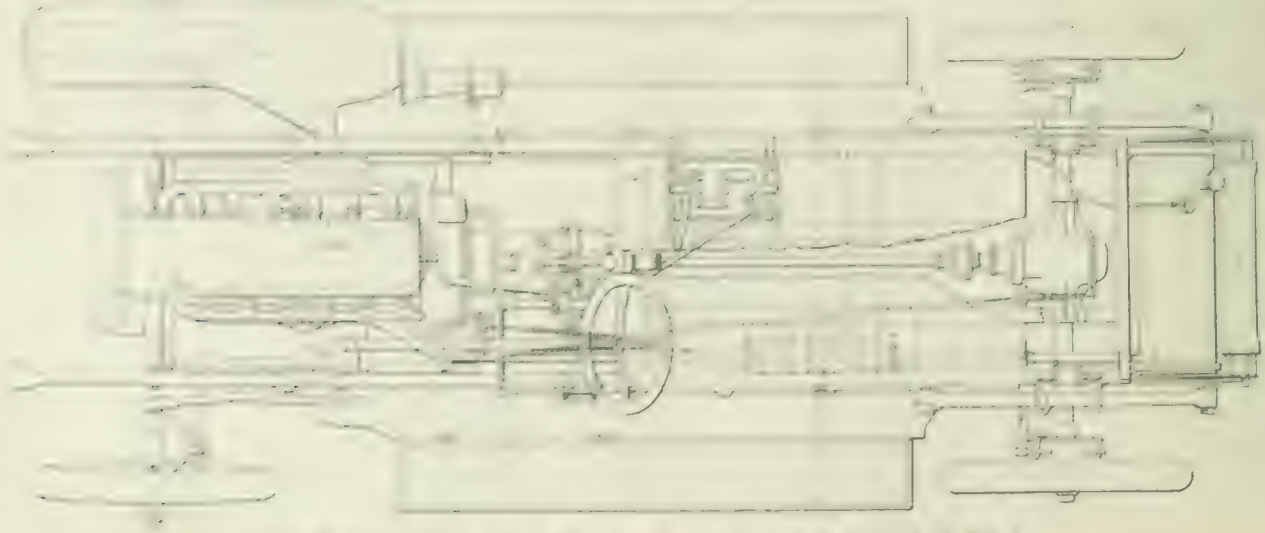
[1] M.S.A.E.—Research engineer, H. H. Franklin Mfg. Co., Syracuse, N. Y.



Figs. 2 and 3 are, respectively, side elevation and plan views of the chassis. Since the chassis of the Series-9 and the Series-10 cars are identical insofar as weight and rolling resistance are concerned, I shall continue to discuss the cooling system in terms of car speed in miles per hour because my curves are all made on this basis. For the assistance of those who may wish to reduce these figures to a practical application, I have computed the diameter of an orifice of equivalent area to that of the total air passages that are formed around the six cylinders of our engine. This equivalent orifice is computed to have a velocity coefficient of 100 per cent. The Series 10-A orifice has an area of 0.306 sq. ft. The Series 9-B orifice has an area of 0.238 sq. ft. The cylinders on the 9-B engine were built on $5\frac{1}{2}$-in. centers; but the cylinders on the 10-A engine are built on 5-in. centers. At a car speed of 20 m.p.h., the 9-B engine delivered 18 cu. ft. per sec. of cooling air as compared with 15 cu. ft. per sec. for the 10-A engine. The back pressure on the 9-B engine was 0.3 in. of water; on the 10-A engine it was 0.6 in. of water. Our Series 10-A car will load perfectly at 5 m.p.h. with a full-open throttle at a temperature of 95 deg. fahr. in the shade for as long as it may be desired to drive up hill at this speed.

I will endeavor to show later, in detail, how we obtained the increased efficiency in the cooling system. The volume of cooling air delivered increases directly with the speed of the engine. The pressure of the cooling air in the duct increases as the square of the speed, while the horsepower consumed by the fan increases as the cube of the speed. We have no desire to use and do not believe in the ultra high-speed engine, but I feel it to be evident to all that it would not be advisable to attempt to cool with the direct-connected fan, since the power it consumes increases as the cube of the engine speed. The power consumed by our cooling fan at 20 m.p.h. is approximately 0.3 hp. At 30 m.p.h. it is 0.8 hp. After making careful comparisons of the power consumed by airplane propeller-blade fans just back of a radiator, I am led to believe that our cooling fan uses no more and, in most cases, decidedly less horsepower to drive it than is consumed by the ordinary fan just back of a radiator. Our grille construction provides a freer passage of air than would be possible with a water-filled radiator. All of the air pumped by our fan acquires a rise in temperature of from 90 to 120 deg. fahr. while passing over the engine, and may reach 220 deg. fahr. at the exit with perfect safety. Since the water-filled radiator never heats the air to more than from 45 to 60 deg. fahr., at least twice the volume would be required for a given cooling with a proportionate increased consumption of fan horsepower.

The water-circulating pump with its driving gear, shaft, bearings and stuffing boxes, can easily absorb as



much power as the water-cooling fan. The increased power losses and the additional complications necessary to operate a water-cooled system have been accepted by a majority of engine builders, but I am convinced that they must recognize the increased efficiency and the direct simplicity that we are able to gain through the use of a single fan wheel mounted on the engine crankshaft, as illustrated in Fig. 4.

When operating on the dynamometer, I have observed that our engine uses approximately 2 cu. ft. per hp. per sec. of cooling air at the lower speeds around 400 to 600 r.p.m. At the higher speeds, the engine uses from 0.9 to 1 cu. ft. per hp. per sec. of air.

Since, for many practical reasons, the fan must be located on the crankshaft, the problem at once presents

TABLE 1—COMPARISON OF COOLING-SYSTEM WEIGHTS, SIX-CYLINDER CARS

Name of Part	Our Car, Lb.	Other Cars, Lb.	
		Car *A*	Car *B*
Fan	14.47	3.2	2.0
Upper Air-Hood	18.31		
Lower Air-Hood	10.66		
Front Fan-Housing	8.25		
One-Half of Rear Fan-Housing	6.56		
Cylinder-Block and Valves	92.64	118.0	99.0
Cylinder-Head			42.0
Radiator Core and Shell		49.0	54.0
Water-Pump		7.5	10.0
Water Hose and Pipes		2.5	1.0(*a*)
Fan Support and Belt		2.0	0.7(*a*)
Thermostat			2.0
Water in System		31.4	37.6
Fan Driving-Pulley		2.0(*a*)	2.0(*a*)
Total Weight	150.89	215.6	250.3
Cylinder Size			
Bore, in.	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{3}{4}$
Stroke, in.	4	$4\frac{1}{2}$	5
Displacement, cu. in.	199	242	268
Weight in Pounds Divided by Cubic-Inch Capacity of Cooling System	0.754	0.891	0.933

(*a*) Indicates approximate weights.

itself how to obtain a sufficient pressure of air at extremely low engine speeds to cool the engine properly. Since it was not desirable to increase the diameter of the fan on account of general bulk and road clearance, we finally tipped the fan blades forward. This arrangement provided an air pressure equal to 1.68 times the peripheral speed of the fan. In other words, we are able to increase the air pressure for a given peripheral speed to the extent of 68 per cent over that which would be obtained by the use of a straight blade. Fig. 5 is a side view of the engine assembly. Fans with different numbers of blades were tried of course.

The next problem was to flow the air into the fan so that it would pass through in an efficient manner. The ordinary sharp-edge square-cornered entrance was found to be impossible because the air did not fill the full width of the blade. Our experiments showed one-third of the blade width to be inactive. We overcame this by using a scrolled-edge entrance, formed with as large a radius as was practicable. A very large radius would increase the entrance losses. A very small radius would increase the fan losses.

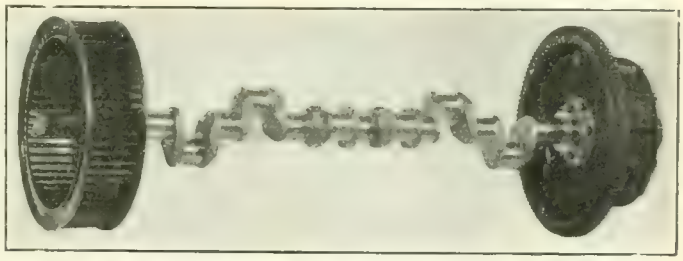


FIG. 4—A SINGLE FAN WHEEL MOUNTED ON THE ENGINE CRANKSHAFT SUPPLIES THE COOLING AIR

Experiments were next conducted with various scrolled shapes in an endeavor to have each square inch of blade area do an equal amount of work. The scroll housing and aluminum ducts were next developed by the elimination of eddies. The distribution of the cooling air so that an equal volume would pass by every cooling fin on each cylinder was accomplished through the use of deflectors in conjunction with the proper shape of the duct. It once required 14 separate pieces to obtain this distribution, but we were able to reduce this number to three pieces of very special shape and yet obtain a uniform distribution of the cooling air with a minimum loss of pressure. The present cooling system draws the air directly through the lower part of the grille at the front of the car, and passes it out through the cylinder fins into the automobile hood. At this point the heated cooling air is diluted by a large volume of free air that is allowed to enter the upper part of the car hood to dilute the hot air and reducing its temperature to a point slightly above that of the surrounding atmosphere, after which it all passes out underneath the car.

It must be evident to all that a direct air-cooling system that would cool properly at 110 deg. fahr. in the shade must over-cool at 10 deg. fahr. below zero. With this extreme in mind, I developed a thermostatic control of the cooling air. This control was operated through the use of a bi-metallic strip, screwed into the cylinder-head, which controlled a connection between the suction-yoke and the operating bellows for the dampers. This system gave remarkably close regulation on a car to the extent that the cylinder-head temperature could be maintained at any predetermined point within the range of ± 25 deg. fahr. This system also was arranged so that, in case the orifice became plugged-up or a pipe became broken, the dampers would be opened by the force of a spring and would remain in this position until the difficulty could be overcome. This idea was of great as-

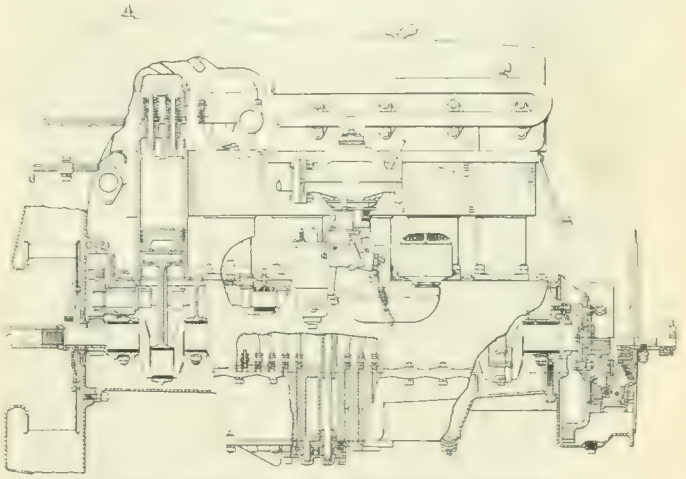


FIG. 5 SIDE VIEW OF THE ENGINE ASSEMBLY

distance on a cold morning in warming up the engine. It showed also a remarkable improvement in gasoline economy. In fact, it proved to be a very efficient and necessary device until we developed the exhaust-heated vaporizer, that maintained the temperature of the suction-gases at 140 deg. fahr. ± 5 deg. throughout the entire working range of the engine.

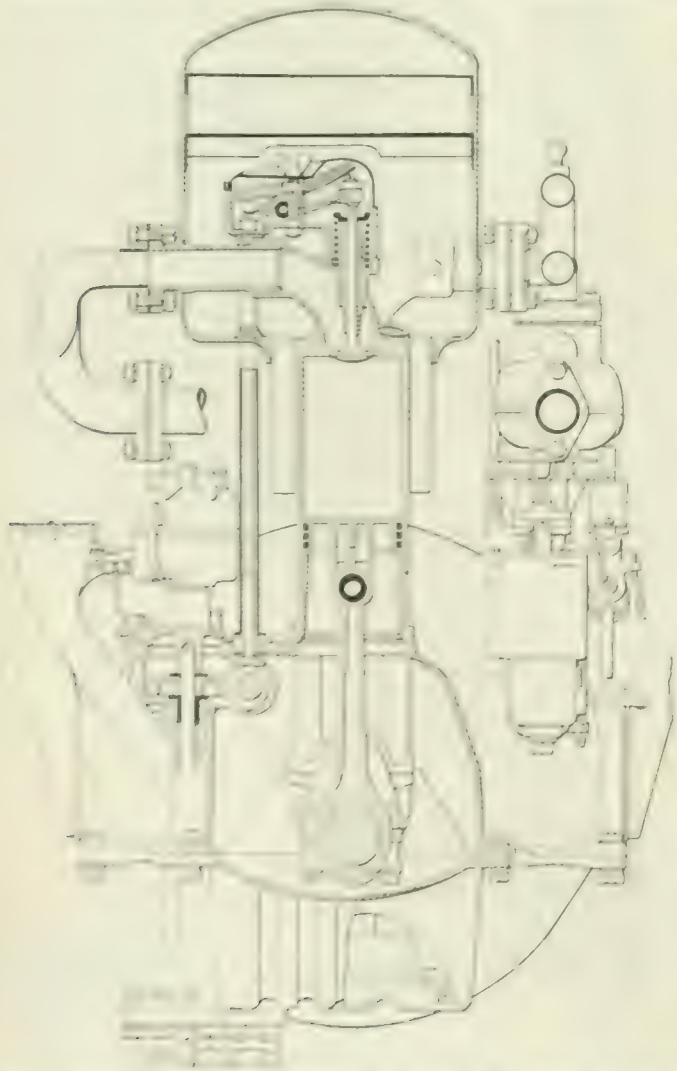
Comparison of Cooling System Weights

A considerable amount of verbal comment has been made, but I have not observed any written comparisons regarding the relative weights of the cooling systems of air versus water. It is difficult to get a truly equitable basis. In this case I selected two prominent six-cylinder engines and have included the complete weight of their cylinder-block and valves against the complete weight of our cylinders with fins and valves, as shown in Table 1.

Since our final weights as well as the weights per cubic inch of displacement are both decidedly less, I am convinced that the direct method of cooling shows a decided advantage in this respect.

Details of Construction

Next to the cooling system, I feel that the cylinder is the most important part of any direct air-cooled engine; it is shown in Fig. 6. The cylinder is designed on 5-in. centers, has a 3¼-in. bore and a 4-in. stroke.



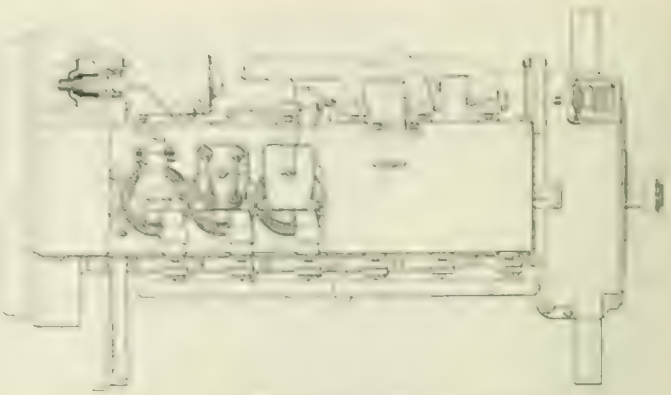


Fig. 7—Plan View of the Engine Assembly

Each cylinder with its valve and springs weighs 15.4 lb. The cylinder fins are 52 in number; they are 5 in. long and 1⅛ in. wide; 1/16 in. of this width is cast into the cylinder and 5/16 in. of it is turned over on the outer edge so that each fin can form its own jacket. This arrangement allows the jacket to assume the role of direct radiation. Each cylinder with its fins and exposed heat area has a radiating surface of 650 sq. in. While passing through the development stage, we built cylinders of aluminum, of bronze and of various combinations of metal. The cylinder shown in Fig. 6 has proved itself to be preferable in every respect to all the others that we have tried. When using a cylinder fin of greater length, we observed an increase of the weight and an increase of the air resistance, but did not observe a proportionate increase in the cooling ability because it is just possible that the air reached a very high temperature before it had traversed the complete length of the fin. We tried fins of one-half the present thickness, which would be 0.026 in., but found them to be impracticable because the air passages were so small that mud, grasshoppers and bugs closed the opening and made the engine overheat exactly in the same way as it would do with any water-cooled radiator.

Foundry Production Practice

As to foundry production methods, a steel cylinder with machined grooves along its length is first loaded with fins that are held in place by an ordinary soft-iron wire. This is placed in the mold and sand is allowed to fill-in between the fins. The steel cylinder is then very carefully extracted, exposing 1/16 in. of the edge on all of the fins. The suction and the exhaust ports and ducts are formed in cores and added as a unit. The cylinder is poured on-end with the head down. No heat-treatment is used in the process of the construction of this cylinder. When completed, the combustion-chamber has been machined and the bore ground to size; there is a wall thickness of 3/16 in. under the steel fins. This thickness is very necessary to give assurance that no hard spots appear along the bore. Before delivering the cooling fins to the foundry we found it advisable to tin them all over, which then assures us of practically a 100-per cent union between the fins and the cylinder-walls. The head of our cylinder is ⅝ in. thick. We have tried heads decidedly thinner and some 2 in. thick. We met with absolute success on all heads thicker than ⅝ in., but found that the extremely thin heads did not provide a sufficiently uniform temperature around the exhaust-valve seat.

Those who have endeavored to produce a quiet overhead-valve mechanism will appreciate our problem when I say that the expansion of our cylinder alone amounts

to 0.019 in. and that the exhaust-valve stem adds another 0.007 in., making a total of 0.026 in. that must be compensated for to maintain a uniform rocker-arm clearance at the valve-stem. The assembly shown in Fig. 7 provides for a normal adjustment of 0.010 in. at room temperature and a maximum variation of ± 0.002 in. within the range of cylinder temperatures from zero to 400 deg. fahr.

We mount our rocker-arm housing on top of the cylinder just beyond the valve-stem on one side, and we support the opposite side on two metal tubes that are concentric with the push-rod. This forms a semi-flexible arrangement, that can go-and-come with the expansion of the parts, yet it does not change the tappet clearance. The valve-springs on our engine "shimmy" at a number of different speeds. I have tried four different sizes of wire and two different diameters of spring, also one taper spring, but cannot seem to get rid of this peculiar action. I make a special appeal for suggestions as to

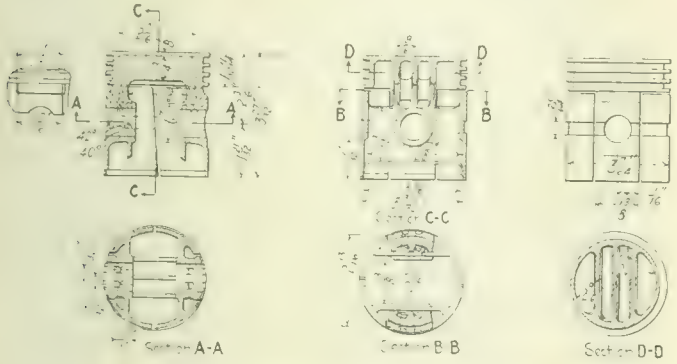


Fig. 8—Elevation and Cross-Sections of the Piston

how to overcome the shimmy or period points best in a plain valve-spring.

Fig. 8 shows section views of the piston. We have developed three distinct types of piston construction suitable for production. In all three an attempt has been made to isolate the ring-carrying portion from the skirt portion. Two of the types are sawed through and one is cast exceedingly thin at one point. The two that are sawed through have heavy supporting ribs under a ⅛-in. head; the third has an exceedingly thick head-construction. At present, I feel that the thick head-construction is less apt to collect carbon on the top, and shows itself to be almost entirely free of oil burning underneath. The true cylindrical non-split type seems to run with the least friction. The question of being able to free it permanently from sticking or scoring on the one hand, and from slaps on the other, can be solved only by trial. At present, and for a number of months previous, we have had remarkable success with a split-skirt type in which we use three rings. The top one is a plain concentric snap-ring; the middle ring has a special three-piece construction; and the bottom ring is a one-piece concentric snap-ring machined with a sharp edge for wiping oil. Piston and ring theories are numerous. We want the rings to wear-in quickly and to maintain a perfect bearing, and yet not to wear-out or break-out. Some types are far superior to others, but I feel that the technique of fabrication is of more importance than the design alone.

The forged duralumin connecting-rods shown in Fig. 9 are the result of a long series of experiments on the shape and the area of the various sections. Our steel connecting-rod would weigh 1 lb. 15 oz. complete, but our duralumin forged connecting-rod now weighs only

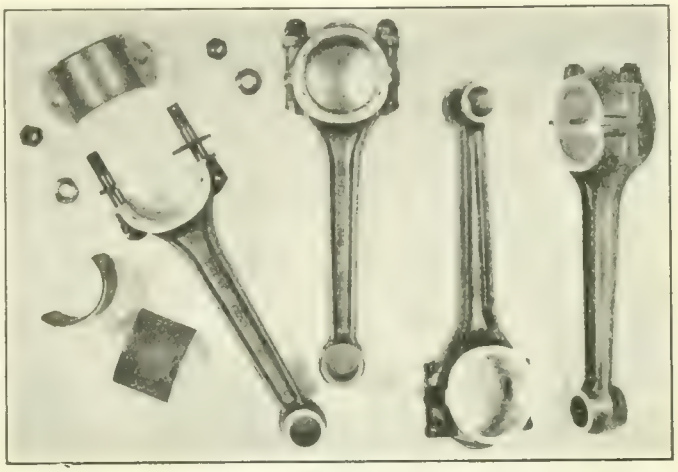


Fig. 9—View Showing the Parts Entering into the Forged Duralumin Connecting-Rod and the Rod Completely Assembled

1 lb. 4 oz. complete. The piston-pin floats in the rod and in the piston. The hole in the rod is reamed to within 0.0005 in. of the finished-diameter in two operations. The hole is then burnished to size the same as is done in the piston. This produces a very superior finish in the hole, that seems to possess remarkable wearing qualities. After the die-cast bushings are locked by grooves into the big end, a combined swaging and burnishing operation packs the babbitt and produces an intimate contact with the rod at all points. The cap is assembled with babbitt-faced shims, after which a fly cutter pro-

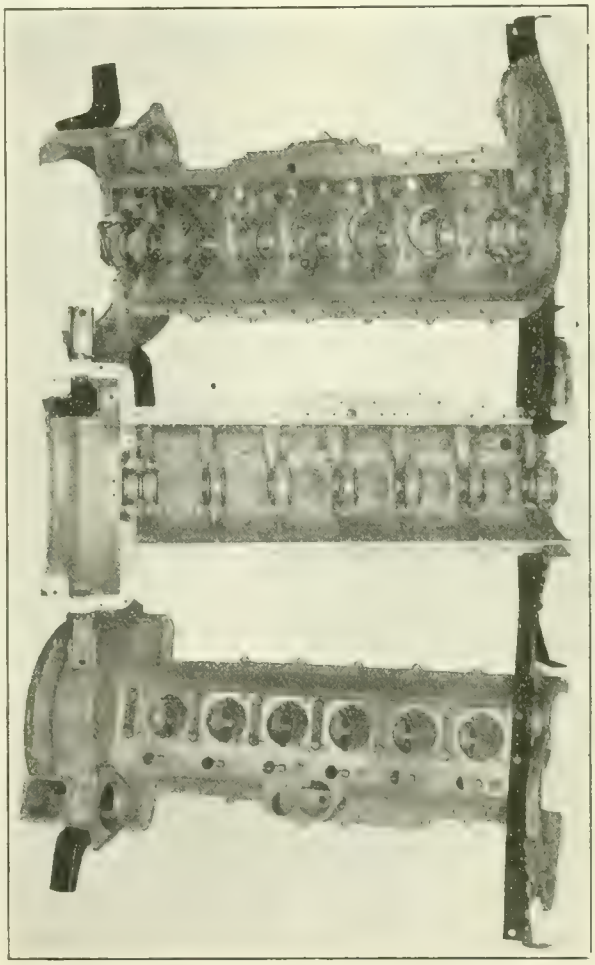


Fig. 10—Three Views of the Cast Aluminum Crankcase

cross a true cylinder for the bearing surface. These cylinders are to five diameters and vary by 0.00025 in., which means it is possible to select a rod for each crankpin that will have an oil clearance of 0.001 in. When completed, the assembly of rod, piston-pin to crankpin, is held to a limit of ±0.005 in., measured between the ends of arbors 12 in. long. The maximum allowable difference in weight between any two rods in an engine is less than 0.2 oz.

Nothing but a seven-bearing crankshaft has been used in our six-cylinder engine. Our present shaft is 2 in. in diameter at the crank and the main bearings. They are forged from 0.15 to 0.20-per cent carbon-steel. The throws are then twisted to position and the whole shaft, after being rough machined, is copper-plated except at the bearing points where the carburizing process is allowed to act. The shaft is then straightened and heated to 1420 deg. fahr., clamped into a powerful holding jig and quenched in water. It is then finish-ground to size. The case formed at the bearing points is 1/16 in. deep and registers 75 to 85 on the scleroscope. This case-hardened shaft, working against soft babbitts, will not need bearing attention until after 50,000 miles of running.

The crankcase shown in Fig. 10 is cast of aluminum, is unusually deep and is split 2 1/2 in. below the shaft center-line. The seven bearing-caps are die-cast and held in place by through bolts seated against pressed-steel plates located on the top between the cylinders. The seven main bearings and the four camshaft bearings are rigidly supported by deep-ribbed sections. The main bearings are fly cut and reamed to size. The bell housing is fly cut from the finished bearings to provide an accurate alignment with the transmission.

There is a separate duralumin flange between the cam gear-housing and the generator, on the hub of which the chain sprocket rides. This permits the generator to be removed without disturbing the chain drive; it also allows a quick and accurate chain adjustment. The chain tension can be measured through a hole especially provided for this purpose.

Lubrication

When operating an air-cooled engine throughout the Country, with all its variations of roads and temperatures, the problem of lubrication assumes a position of considerable importance. The lubrication system is indicated in Fig. 5. Our cylinder-head temperature often reaches 400 deg. fahr. Our experience in the air-cooled-engine business has convinced us that the lubricating oil for our engine should be as free as possible from carbon. For this reason we are continually inspecting samples of oil from all of our dealers as well as from the principal vendors. This has allowed us to specify to our dealers and customers an oil that we have found to be reasonably uniform throughout the United States and to obtain the minimum of carbon residue.

A simple oil test can be conducted as follows: Obtain two bulbs from an electric fire-place heater, they will be about 2 1/2 in. in diameter, 12 in. long and should consume 500 watts. Mount them on a slant with the socket end up. Arrange the oil so that it will drip on to the upper end of the bulb. That portion not vaporized will continue around either side and drop from the bulb at the lower end. These drippings are caught on a clean blotter. Any desired quantity of oil can be run, but 4 qt. should be sufficient. The formation of a black ring around and on the blotter can be taken as an indication of the carbon residue from that particular oil that would probably lodge in the combustion-chamber as a carbon deposit.

Our engine has a seven-bearing crankshaft and is supplied with oil by a force-feed distributor-system. The oil-pump is driven from the camshaft and is located in the base of the oil-pan. Oil is drawn upward through a bronze screen that has an area of approximately 50 sq. in. From the pump distributor-plate, oil leads extend to all of the seven main bearings and to the chain gear bearing on the generator support. Each connecting-rod receives oil under pressure from its adjacent main bearing. The oil-pan is of cast aluminum and has corrugations in the bottom that are a material aid in maintaining the oil temperature at a reasonable figure of 160 deg. fahr. on a hot summer day. The one outstanding feature of this particular oiling system is the fact that, if for any reason one of the connecting-rods or one of the main bearings should burn out, the volume of oil that would be forced to the remaining bearings would not be altered. It has happened in our experiments that this particular feature was of great value and allowed the car to run all day with the knowledge that there was no chance for injuring anything, more than the particular bearing that had already gone. In an interesting experiment with baffle-plates located between the cylinder and the crankcase, we found that the baffle-plates increased the oil consumption at high speed and decreased it at low speed. We observed also that those baffles that had the smallest openings for allowing the connecting-rod to pass through showed the greatest effect.

For a given uniform extremely hot oil-temperature of approximately 205 deg., the pressure of the oil at both the pump and in the lead increases as the first power of the engine speed. At a uniform engine speed of 1800 r.p.m., the volume of oil forced through the bearings does not change over our practical or wide range of oil temperature and, at the same uniform engine speed, the oil pressure decreases with an increase of the oil temperature. In other words, our pump meters out a definite quantity of oil and forces this quantity to the bearing, regardless of the pressure required or the temperature of the oil pumped.

The automobile builder states how far his car will run on a gallon of oil; he says that if the oil-pan holds from 5 to 8 qt. the oil should be changed each 500 miles. When operating our car over 100 miles for each consecutive 3 hr., the oil consumption is 400 miles per gal.; when operating ordinarily, it is 800 miles per gal.

The oil-pump is arranged so that we can supply any desired quantity of oil to our engine. We have operated our cars successfully at the rate of 1200 miles per gal. but we feel that this is very inadvisable and have established the rates just given. I do not understand how an owner can profit by reducing his oil consumption to the minimum, in some cases practically starving the engine. We have been working on devices for the elimination of crankcase dilution for the past 2 years and have developed a unit that we believe will eliminate all crankcase dilution.

Exhaust-Heated Vaporizer

While working for an improved fuel-economy, I developed an automatic vacuum-controlled spark-advance. Our ignition is now controlled by a mechanical governor that is very carefully calibrated for all conditions of full-throttle work. The vacuum-actuated bellows worked against a calibrated spring to increase the spark advance in the proportion of 1 divided by the absolute compres-

sion-pressure in the cylinder. This device improved the economy from 5 to 18 per cent. Next, I developed and installed a thermostatic control for the cooling air. The bi-metallic strip located in the cylinder-head allowed a connection with the suction yoke to operate a sylphon bellows connected in turn to dampers in the air duct. This operated very satisfactorily; I could control the cylinder-head temperature to ± 25 deg. fahr. When set for from 400 to 450 deg. fahr., the economy was increased materially.

My next development was an exhaust-heated vaporizer, shown in Fig. 11, in which a return trap for all wall-flow of fuel not vaporized on the first trip through was incorporated. The vaporizer performed better than my expectation, a glass tube located above and below showed clearly that all of the fuel was actually converted into a vapor. A thermocouple located at the yoke exit and

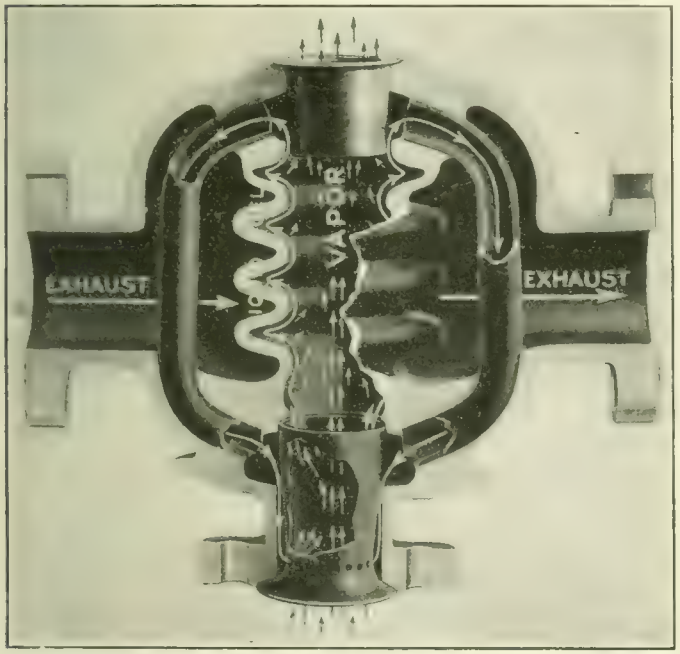


Fig. 11 An Exhaust-Heated Vaporizer in Which a Return Trap for All Wall-Flow of Fuel Not Vaporized on the First Trip Through is Incorporated

suspended in the middle of the gas stream was used to determine the yoke temperature which remained at 160 deg. fahr. ± 5 deg. over all conditions of throttle and load at all speeds except those of less than 20 m.p.h., at which speed the yoke temperature was approximately 15 deg. fahr. cooler. Continued research with the vaporizer soon convinced me that, with it installed, I could no longer show an appreciable saving in economy either with the vacuum spark-control or the thermostatic temperature-control of the cylinder-head. This has proved out very well commercially, because we were able to install a plain casting having no moving parts that replaced two mechanical devices.

Our carbureter, shown in Fig. 12, is very simple. It consists of a plain gasoline nozzle controlled by an adjustable needle from the cowl. This nozzle is located in the primary choke. Extra air is supplied through a plain hinged valve for auxiliary air that has an adjustable spring. The float mechanism is arranged so that the weight of the float, by a lever, lifts the gasoline needle from the seat. We find the practical operation of a single large easily variable fuel-orifice offers many advantages; chief among them is our ability to adjust immediately

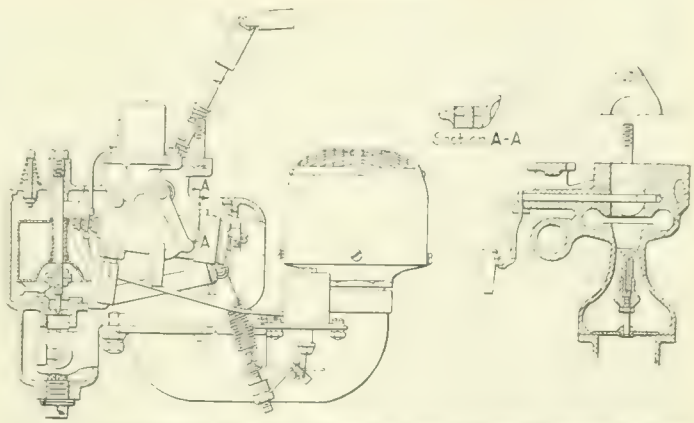


Fig. 12—Elevation Partly in Section and a Cross-Section of the Carbureter

for any change in the fuel quality and to be able to free the orifice from water or dirt readily when occasion demands.

Special efforts have been made in the design of the carbureter to facilitate starting in cold weather; to this end, for starting, the gasoline is vaporized and superheated electrically. This feature can be best explained by referring to the cut-away view in Fig. 13.

A miniature valveless carbureter has been constructed adjacent to the main instrument and draws its fuel from the common chamber. All the gasoline and the priming air pass over an electrically heated coil and are converted into a fixed gray vapor. This joins with the auxiliary air and passes up through a solenoid-controlled valve into the suction yoke just above the throttle disc that is always closed during this period.

To start in cold weather, the method is to close the throttle tight, open the gasoline needle-valve one entire

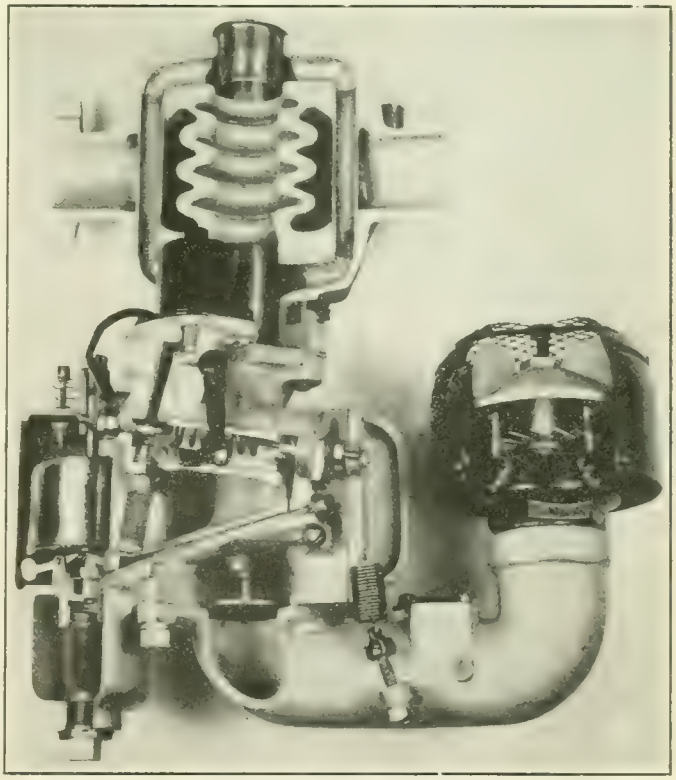


Fig. 13—A View of the Carbureter Partially Cut-Away to Show the Electric Heating Arrangement Provided for Use in Cold Weather

	Our Car		Other Cars	
	Amp.	Sec.	Amp.	Sec.
[illegible]	80	30	400	90
[illegible]	400	10	400	10
Total Energy	7,200		10,000	

A comparison of the starting conditions is made in Table 2. It shows a direct saving for our starting system of 32,800 amp.-sec. out of 40,000; or a saving of [illegible] 40,000 = 82 per cent of battery energy. After the engine has fired for 1 min. at 20 deg. fahr. below zero, the aluminum exhaust-vaporizer has become sufficiently heated to run the engine directly from the main carbureter. Our machine is a dependable all-year car because it will start and run, even at 20 deg. fahr. below zero, with the expenditure of less than one-fifth of the battery energy usually required. The engine gets a rich mixture from the vaporizer and fires slowly at first. The throttle-valve is then opened slightly until the engine has picked-up somewhat. As soon as possible, the gasoline needle-valve opening is decreased to the running position of five-eighths of one turn. During warm weather and in mild climates, it is not necessary to use the electric primer.

Dust Separator

[illegible] carbureter has been arranged to pass all of the air through a common opening, it was easy to provide it with a dust separator. Its total weight is 14 oz. and it is illustrated in Fig. 13. This separator consists essentially of two units, both of which are mounted on the same shaft and rotate together. The lower unit is a centrifugal type of motor that receives its power from the air flowing to the carbureter. This causes the upper member or centrifugal pump to inhale into the housing a little greater volume of air than is used by the carbureter. Thus the same duct with its radial vanes travels at high speed, all dust particles are thrown centrifugally against the side walls of the housing. At the lower edge of this housing is an opening about ½ in. wide extending [illegible] around the instrument.

Since the centrifugal pump has inhaled 30 per cent more air than can be used by the engine and has forced all dirt particles by centrifugal force into this excess air, the dirt is carried away in this excess air, out through the bottom of the housing, and discharged to the atmosphere. As a test, I secured fine dust-particles from a dust separator; these particles had all been air-floated previous to their separation. I fed a definite quantity very slowly into the separator, which was operated at low speed with 1 in. of water suction. Careful weighing, in two tests, convinced me that this separator actually would clean from 96 to 97 per cent of the extremely fine dust particles from the airstream. This separator has greatly increased the life of the bearings and decreased the amount of carbon deposit in the combustion-chamber. The rotor runs fast enough to enable it to separate the dust at all car speeds above 3 m.p.h.

Operation

Our engine cylinder will not give satisfactory operation when the compression pressure exceeds 80 lb. per sq. in. gage, but they are working with absolute satisfaction at a speed of from 400 to 2500 r.p.m. and a compression pressure of 75 lb. per sq. in., measured with an accurate indicator. This refers to the use of low quality plain 18-cent gasoline.

I recently drove a car that showed rough engine operation and was informed that, whenever a compression pressure of 92 lb. per sq. in., or a brake mean-effective pressure of 97 lb. per sq. in. was used, this roughness could not be avoided. I have used our engine with a 5 to 1 ratio and found it snappy, and I have also used a 4 to 1 ratio with equal snap and obtained a decidedly smoother flow of power. With our cylinder, the amount of horsepower does not increase with the compression ratio above 4½ to 1. The volumetric efficiency decreases rapidly with an increase of the cylinder-head temperature resulting from a high compression-ratio. The lower compression-ratios can be made to give a higher volumetric efficiency, and therefore greater power from the same cylinder. The preignition point is the sum of the yoke temperature plus that of compression.

Our air-cooled cylinder will run satisfactorily up to a 630-deg. fahr. cylinder-head temperature, provided the sum of the yoke and the compression temperatures does not exceed that of the preignition point. The higher head-temperature will cool the engine at a greater horsepower on account of the increased temperature-difference between the cylinder and the cooling air.

Our present Series-10 powerplant has a compression ratio of 4.22 to 1, a compression pressure of 72 lb. per sq. in. at 400 r.p.m. and develops 24 hp. at 1800 r.p.m. with a cylinder-head temperature of 390 deg. fahr. when the cooling air enters at 85 deg. fahr. To obtain more horsepower, we would reduce the compression ratio and accomplish this result with the same bore and stroke.

The suction-yoke temperature on our Series-10 engine is now located at 160 deg. fahr. ± 5 deg. fahr. at which point we introduce a perfectly dry gas into the yoke. Should the yoke temperature rise to 180 deg. fahr. when the atmospheric temperature is 110 deg. fahr. in the shade, the engine would "ping"; should it drop to 110 deg. fahr., the smooth even flow of power would diminish in quantity and the economy would suffer.

The term, "compression ratio" is used frequently, and I often wonder if the public comprehends how misleading it is when discussed in connection with compressions or in connection with the number of miles per gallon. As an illustration, on wide-open throttle, I have measured an actual compression-pressure of only 60 lb. per sq. in. with a 5 to 1 ratio and have also measured a pressure

of 77 lb. per sq. in. with a 4 to 1 ratio. Both readings are true and consistent but, in themselves, they mean nothing unless something is known of the valve-timing, the yoke temperature and the manifold depression, as well as something of the port passages. To my mind, nothing could be more absurd than to use compression ratio as a basis for statements about miles per gallon on an automobile.

Our average touring car alone weighs 2450 lb. and an average five-passenger load weighs 750 lb.; therefore, the total running weight is 3200 lb. At a car speed of 20 m.p.h. at full throttle, the engine develops a brake mean-effective pressure of 75 lb. per sq. in. when using a mixture-ratio of 17 to 1, at a fuel-consumption rate of 0.607 lb. per hp-hr. At the same car speed, with just enough throttle to maintain this speed on a level road, the engine develops a brake mean-effective pressure of 16 lb. per sq. in. which, with a mixture-ratio of 13.65 to 1, is a fuel-consumption rate of 1.03 lb. per hp-hr. Under these conditions, the car traveled 34.2 miles per gal.

At full throttle, the pumping loss was based on a yoke suction of 1.05 in. of mercury. Under the condition of level-road operation, the pumping losses were increased in proportion to a yoke suction of 17.1 in. of mercury. The rolling friction of the engine does not change appreciably with load and, at 20 m.p.h., has a value of 8.5 lb. in terms of brake mean-effective pressure. The value of the increased pumping loss is $\frac{1}{2}$ (17.1 — 1.05) = 8 lb. per sq. in.

A brief analysis of the dissipated energy in the two cases stated at full load and at part load, is given in Table 3.

TABLE 3—ANALYSIS OF ENERGY DISSIPATED

	Full Load	Part Load
Brake mean effective pressure, lb. per sq. in.	75.0	16.0
Friction, lb. per sq. in.	8.5	8.5
Pumping loss, lb. per sq. in.	——	8.0
Total, lb. per sq. in.	83.5	32.5
Proportion of mean effective pressure generated that was utilized, per cent	90	49
Actual rate of power generation, lb. per hp. per hr.	0.546	0.505

Our company has endeavored to eliminate this waste by producing a car having a powerplant that will deliver 24 hp. at 40 m.p.h., when it knows that only 12.37 hp. is required to operate a two to five-passenger load on a level road. The car will travel 50 m.p.h. on the level. Were we to install a 45 to 80-hp. engine and build this car to endure, we would at once sacrifice its characteristics of light unsprung weight, remarkable fuel-economy, superior riding qualities and low maintenance cost. Our average stock car will accelerate with a full five-passenger load from 5 to 15 m.p.h. in less than 5 sec.; from 5 to 25 m.p.h. in less than 10 sec.; and from 5 to 35 m.p.h. in less than 15 sec. It can be throttled down to 3 m.p.h. in high gear, and it will run at a speed of 50 m.p.h. on a level road.

THE DISCUSSION

C. L. LAWRANCE:—As an aircraft-engine designer, the part of the paper that interests me most is the part dealing with engine performance. It is stated that the amount of horsepower does not increase with the compression ratio above a ratio of 4½ to 1, and that an actual compression-ratio of 4.22 to 1 is used, which corresponds with good motor-car practice and, for many reasons, it probably is undesirable to use a higher compression than this. However, the fact that the amount of horsepower does not increase for compression ratios above 4½ to 1 indicates that the cooling system is only just ample for the use for which the engine is intended; either the air is not sufficient in quantity or does not come into contact equally with all parts of the head, or perhaps the cooling area of the head is not sufficient. At any rate it is well known, especially in aircraft work, that it is possible to use successfully compression-ratios much higher than this.

The most interesting case of this is a recent experiment made by S. D. Heron at McCook Field while testing a cylinder of 4½-in. bore and 5½-in. stroke, having a cast-iron head and a combustion-chamber threaded on to a steel barrel. With a compression-ratio of 5.3 to 1, a brake mean-effective pressure of 130 lb. per sq. in. was consistently obtained, although the head temperature at certain points reached as high a value as 900 deg. fahr. It is fair to say that the head of this cylinder was considerably thicker than is the usual practice with cast iron, having been cast from a pattern that was intended for making aluminum cylinder-heads.

Our experience with various compressions leads us to believe that, all other things being equal, high compression with proper cooling will always give a better fuel-economy than a lower compression. Therefore, I believe that Mr. Grimes' illustration in which he compares two engines, one with a 5-to-1 compression ratio that shows only 60 lb. per sq. in. compression at open throttle, and another engine having a 4-to-1 ratio with 77-lb. per sq. in. compression, does not represent a fair comparison unless both engines are identical in every other respect.

I have just returned from Europe, and there is practically nothing to report with regard to air-cooled motor-car engines as no air-cooled European motor-car of the price and quality of the car Mr. Grimes represents is being built on the other side. However, I saw a large quantity of small cycle-cars being produced with the BSA engine that S. D. Heron described in his paper on Some Aspects of Air-Cooled Cylinder Design and Development.[2]

In England, a considerable amount of aircraft air-cooled engine development is in progress. The British Air Service is using a number of ABC Cosmos and Armstrong Siddeley air-cooled engines. The feeling there is that water-cooled aircraft-engines have seen their day, at least for most types of military aircraft. However, this was not true in France where, so far as I know, no air-cooled engines were in use. I saw an experimental one-cylinder air-cooled engine on test at the Royal Aircraft Establishment at Farnborough, that used the direct injection of the gasoline fuel. I was told that it showed a mean-effective pressure of 170 lb. per sq. in. This seems to indicate that the development of the four-cycle internal-combustion engine has by no means reached its limit.

C. P. GRIMES:—I have long known of your remarkable pioneer work in air-cooled engine construction. I know that you have been able to

(1) Build a lighter engine per horsepower
(2) Develop a greater horsepower per cubic inch of displacement
(3) Use less fuel per brake-horsepower hour

when using a compression ratio of 5 to 1 as against 4 to 1 with an aluminum air cooled cylinder.

We are not assured that our cars will be supplied with

[2] See THE JOURNAL, April, 1922, p. 231.

air pump high test gasoline or heated mixture. It actually requires 5 hp. to produce a cooling air blast across just the fins of 90 m.p.h., which is the minimum velocity encountered by your engine mounted in the slip stream of your propeller.

Our engine must maintain its desirable characteristics of power, flexibility and economy over a period of from 10,000 to 10,000 miles of operation before overhauling was part of it. Ninety per cent of our entire mileage is covered at speeds of between 20 and 30 m.p.h. Our five-passenger car loaded requires 3.2 hp. at 20 and 7.2 hp. at 30 m.p.h. to roll it.

Suppose I did raise the compression to 5 to 1 and added a parasite resistance of from 3½ to 4 additional fan h.p. all for the sake of being able to operate this car for less than 10 per cent of its entire mileage with a compression ratio of 5 to 1 and a cooling air velocity of 90 m.p.h. not just when I pleased but only when I saw fit to spend 40 cents per gal. for airplane fuel and could afford to pay for a complete overhaul every few thousand miles.

If our Franklin car could fly or if it were to run on the top of Pikes Peak I would most assuredly make it with a 5 to 1 ratio with the full knowledge that the actual engine compression pressures would then be practically the same as we now get with a 4.2 to 1 ratio at sea level.

Mr. Lawrence's statement "that high compression with proper cooling will always give better fuel economy than a low compression" does not agree with the facts in my automobile experience.

Ninety per cent of our car mileage is run on 20 per cent of the maximum engine power and requires an average of 5 b. hp. A cooling blast of 90 m.p.h. will require an average of 4 b. hp. additional just for the fan alone. Are we willing to increase the brake load 80 per cent for 90 per cent of the car life in the hope that a rise in the compression ratio from 4.22 to 1 to 5 to 1 will show sufficient economy in the use of 40-cent airplane gasoline to pay for this kind of an engine.

HERBERT CHASE:—What compression ratio is used and what actual compression pressure is realized at the speeds of maximum torque and of maximum power?

MR. GRIMES:—We use a 4.22 to 1 ratio. The maximum torque comes at 900 r.p.m. and a compression pressure of 70 lb. per sq. in. and the maximum power at 1800 r.p.m. and 65 lb. per sq. in.

H. SHEAFF:—Has Mr. Grimes any figure on the bearing pressure of duralumin, that he has obtained by tests?

MR. GRIMES:—No. It must have good lubrication and bear on a polished surface having a sclescope hardness of 70.

J. G. PERRIN:—I have been deeply interested in the air-cooled-engine problem for some time. Two years ago I went to England to see what they had discovered during the war. Prof. A. H. Gibson read a paper on "Air-Cooling of Aircraft Engines," over there. He said they had discovered a way to make the thickness of the cylinder greater than was ordinarily believed necessary. They found that the greater thickness conducted the heat better than the thinner section. It might be of help to know this if certain cases.

Has any work been done in adapting the Knight sleeve-type engine to air-cooled work? The Knight engine is said to be a very quiet engine. Has there been any development or have any experiments been carried on regarding the possibilities of using a valve action such as sleeve-valves rather than poppet-valves in air-cooled engines? We all know that poppet-valves are very noisy in air-cooled engines due to the large clearances. With this forced air-cooling system as used by the Franklin Company can a Knight sleeve-type engine be cooled?

I believe that we are just on the verge of great developments in air-cooled automobile engines. So far, Mr. Grimes' company has tackled the problem in the most consistent way; it has built an air-cooled engine and then built an automobile around it. So many people have done the opposite. I believe that is a very fundamental point.

What has been the experience regarding the life of the cylinders in connection with the use of aluminum pistons? So many of us have had the experience that aluminum pistons lap the cylinders. With an air-cleaner, it seems to me that trouble will be solved. Has any difference been noticed in the life of the cylinders and the pistons, in connection with the use of an air-cleaning device?

MR. GRIMES:—We have observed that the thicker metal gave a better distribution of heat and in that way might aid its dissipation. However, in general we use the thinnest possible metal thickness because we find that the heat travels through faster.

Considerable work has been done by others with a Knight sleeve-type engine. Whereas, I do not believe that a double sleeve-valve engine can be developed with the same high efficiency as a poppet-valve engine, I do know that the Knight sleeve-valve engine can be adapted to air cooling if an aluminum cylinder-head is used. As a result of various tests with iron and aluminum cylinder-heads, I was given to understand that the engine would not be a success were it not for the use of the aluminum head that has capacity for taking away a large quantity of heat.

The Franklin cars have carried dust separators for the past 6 years. I feel that the separator on the Series 10 is far more efficient than any that we have used before. Piston life is very greatly affected by the care used in maintaining proper lubrication for the engine. We expect all of our pistons to last 15,000 miles and find a large percentage of them running 30,000 miles before it is advisable to remove them.

The difference in cleaner efficiency has not been sufficient to warrant my giving a definite statement of increased life.

H. M. CRANE:—It was brought out very clearly in this paper that an automobile today does not depend upon a particular method of cooling. Whether consciously or unconsciously, Mr. Grimes took fully half of his time in bringing out the excellent constructional features of the car, all of which, collectively and individually, have no bearing whatever on the method of cooling the cylinders. He is absolutely right. The public is interested in being moved from place to place, and it will not inquire too closely into how it is done, as long as it is done successfully, at a moderate cost and without too much trouble on its part.

I would like to repeat what I said at Dayton when S. D. Heron's excellent paper on some Aspects of Air-Cooled Cylinder Design and Development[a] was read. His paper, as well as this paper, are a challenge to the designer of water-cooled automobile-engines or water-cooled aircraft-engines. The water-cooled-engine designer has not been forced, until recently, to go into the facts surrounding his method of cooling. He has built a cylinder of a convenient mechanical shape, placed his valves where he wanted to place them and operated his piston in the way that he wished to operate it; then he has put a jacket on, poured some water in and said that

it was properly cooled. The water might disagree with him. Frequently, the water does not go where the designer intends it to go. Few designers, until recently, have made any great effort to find out just what the water does in the jackets.

We had an analogous case on the Liberty engine, when we investigated it, with reference to the lubricating system. Some people concerned in the construction of the engine thought it was a good point that the engine did not require any oil radiator; in other words, that the lubricating oil that passed through the crankshaft did not get hot. The failures in those days were due to the fact that the crankshaft oil did not get hot; in other words it was not doing its part in cooling the crankshaft bearings. That was overcome by installing an oil pressure-lubricating system with a more active circulation. The same condition may be found in the cooling water of water-cooled cylinders. When corrected a larger radiator may be required, but the engine will run very much better.

Of the two types of engine, we may finally come to a division in point of size. The large air-cooled cylinders, while they have proved successful on test-blocks, have not given great success in practice so far. In aircraft engines, part of this is due to the head-resistance and to the great difficulty of controlling the valve-gear with reasonable weight and reasonable head-resistance. The expansion difficulty has been described and the ingenious method that Mr. Grimes' company uses for surmounting it.

Another feature of the air-cooled engine is that, in certain ways, it is far less accessible than the water-cooled engine. In its successful operation, it is practically limited to the valve-in-head type, with the valves integral and without detachable heads; in other words, any work to be done on a valve requires the lifting of a cylinder. The lifting of cylinders, in the hands of the casual owner, is a job not to be encouraged. The most difficult engine problem we have is to maintain the piston and ring seal in good condition; but the average owner, in lifting and replacing cylinders, is apt to make more trouble at this point than he will cure in the valves.

I have recently built an engine having an overhead camshaft, with an integral head carrying over the six cylinders but with the head detachable and the valves all in the head. We had it on the road only about 2 months before things occurred that made us want to look into the cylinders. We were not obliged to do this. The engine would operate and we could get over the ground with it, but there were certain things that we wanted to see. It took considerable determination to take the head off. I think that it ought not to be necessary to make access to the valves and the combustion chamber a difficult and tedious job or one requiring the disturbing of parts having no bearing on the work in question.

The tightness of an engine has much to do with its successful operation and even more with its economical operation. To encourage the operation of engines with leaky valves or leaky pipe connections, which I think might easily be the result of the slip-joints mentioned in the inlet-pipe design is not to the best interest of the automobile-using public. That is especially true in the larger engines. In the smaller ones, I think that we may find the field for air-cooling is widening all the time. It undoubtedly is widening and, if not, that will not be for the lack of the highest grade of research work, some results of which have been given in Mr. Grimes' paper.

MR. GRIMES:—I appreciate the remarks of Mr. Crane and will say that we feel our engine is far more accessible than the ordinary engine because we can remove any cylinder that we wish after the removal of nine nuts, each one of which is extremely accessible. I regret that Mr. Crane has not had an opportunity of becoming more familiar with our latest model engine, which is very accessible.

N. A. HOLLISTER:—The object of using the curved inlet to the fan wheel is not only to increase the capacity but it is also to increase the efficiency. Where only a small space is allowed the whole blade must be used effectively or the fan will not handle enough air. On the larger jobs such as those for big power companies where the power is a factor we increase the efficiency greatly by streamlining the inlet, such as has been done in connection with airplanes.

There was another way of increasing the efficiency of the Franklin car fan. We used to make a fan called a cone fan that was designed for discharging into space without a housing around it. We do not, however, get the efficiency with a cone fan or Sirocco fan discharging into space without a housing, that we do with a housed wheel such as used on the new Franklin model. The air will not be delivered as efficiently from an open wheel as it will if the wheel has a housing with the right scroll and the wheel is in the housing in the right position. These two points, the proper inlet and the proper housing design, are very important in fan design. I strongly suggest that the designer of an air cooled engine confer with the fan man, and as one speaker has mentioned design the engine with its cooling system and then build the car around it.

The importance of air cooling can be gaged by the many inquiries we have received, and we are working now on air-cooling problems for many companies. This air-cooling of engines, not only for automobiles but for other industrial usage, has aroused interest and I predict that it will not be many years before many trucks will be air cooled.

As to price, one company has a fan that is driven by a belt, which means another bearing and another piece of shafting. We can give them a wheel for less than the belts cost them, of course eliminating the extra bearing and, at the same time, handle more air with much less power than they use now. The elimination of freezing and other advantages appear on the face of it, and the fan men believe that the air cooling of engines is coming along rapidly.

MR. GRIMES:—The curved inlet on our fan enabled me to use a much shorter length of blade and thereby increased my overall efficiency.

R. B. WHITTINGHAM:—Was there any intention or expectation of deriving any flywheel effect in changing the position of the Sirocco fan from the rear to the front of the engine? Was that taken into consideration?

MR. GRIMES:—The flywheel effect is there, but the fan is most important. I am not willing to concede that the flywheel at the front end of the shaft is desirable in itself. We have it and our engine runs without producing a vibration period, but I credit that more to a 2-in. bearing on the crankshaft than I do to the flywheel on the shaft. I know of some shafts that had a number of vibration periods and they did place a flywheel at the front end of the shaft. It eliminated all the periods at lower speeds, but it had to be abandoned at the higher speeds. The fan on the front of our shaft is not there for the purpose of producing a flywheel effect, even though it is a flywheel.

C. T. MYERS:—What is the reason for using a 0.01-in.

tures it will be either over-cooled in extremely cold weather or under-cooled in extremely hot weather, which latter condition is likely to cause trouble from detonation or preignition.

It does not appear that the cylinder-head has much provision for cooling and that most of the cooling is carried along the side walls of the cylinder. How does Mr. Grimes control the temperature of the cylinder-head?

MR. GRIMES:—I have definitely determined by exhaustive tests that the temperature of the cylinder-head has nothing to do with the miles per gallon providing, of course, that the suction yoke-gases are delivered in a thoroughly heated and completely vaporized state as is now the case with our present construction.

I would call your attention to the fact that since the car takes but 3.2 hp. at 20 m.p.h. in the summer on a level road that it would not be difficult at all to consume far more horsepower than this in churning over the very heavy oils and grease that are sometimes left in the rear axle and transmission during very cold weather. Thick oil in the crankcase will not give proper lubrication to the cylinder walls. Our present cylinder design gives very satisfactory cooling indeed, even though the majority of the heat must be carried over to the fins and radiated from them.

The cylinder-head temperature is controlled by the gasoline mixture strength, by the compression pressure and by the volume of air passing to the cylinder-head. Our present design seems to have cared for detonation very nicely by eliminating it.

HAROLD L. POPE:—In aircraft work, it is necessary to get a very high mean effective pressure if it is expected to keep the weight per horsepower down to the minimum. I cannot see how the method used in the car under discussion would apply in aircraft work.

MR. GRIMES:—I will refer Mr. Pope to my reply to Mr. Lawrance and feel sure he will appreciate what I have said.

A number of questions have been asked regarding the cooling ability of our car, the amount of airflow and the like. I will simply say that our Series-10 car, with the five-passenger load and luggage, was driven from New York City to Oregon, then to Southern California, through Death Valley, through the Great American Desert and up Pikes Peak. It went far north into very cold country and it crossed the desert very successfully We have made tests repeatedly in which we have run the Series-10 car at 50 m.p.h., with wide-open throttle, up a long hill. Few hills are much over 1 to 2 miles long. We have a hill directly east of Syracuse that many cars cannot negotiate on high gear, yet we can take two people in our Series-10 phæton, that weighs 2450 lb. itself, and negotiate that hill on high gear at 50 m.p.h.

I am not thoroughly satisfied that cooling has nothing to do with preignition. With many water-cooled engines, preignition will occur if the compression-ratio is too high. The practical designer will design his water-cooled engine and will allow a little variation in the piston height, so that he can determine how the carbureter, the ports and the valve-timing work out; then he adjusts their relations so that the engine will work properly. That is all we do.

We have operated our engines from a 3.98-to-1 compression-ratio with our Series-9 car up to a 5 to 1 ratio with our experimental cars. They work well, but the 5-to-1 ratio is altogether too touchy and makes a snappy engine; as soon as a little is deposited, it produces detonation and, as soon as bad fuel is used, the engine is up against it; so, we use a compression of 4.2 to 1, which gives us accurate results with a low grade of fuel.

Our maximum torque does not occur at the maximum power. Our compression pressure for the maximum torque runs about 72 to 73 lb. per sq. in. We try to hold the compression uniform throughout the speed range. We find, by having a uniform compression-pressure throughout the speed range, that a given air-cooled cylinder will cool this uniformly and give us good results. Our maximum brake mean-effective pressure runs about 77 lb. per sq. in. Our phæton weighs 2450 lb. Its speed is 50 m.p.h. At 40 m.p.h. our car requires 12.47 hp. and it has 24 hp. It operates successfully with a wide-open throttle at 25 m.p.h. We believe we have covered the range that we have been asked to cover. Our plan is to try to have the power and the automobile correlated one to the other, so that we get riding power, fuel economy and riding quality all together, and a car that will run as fast as any ordinary person would expect to ride. An analysis of car operation is given in Table 3 of the paper.

Regarding the cooling effect from zero to 120 deg. fahr., in an effort to make a more economical automobile during the development stage, I tried the vacuum-controlled spark-advance, mentioned in the paper. It is well known that when running at part throttle, there is a high suction in the yoke and a low compression-pressure. People talk about high compression-ratio and economy. What good does it do, if you throttle the engine down and do not use it?

Concerning the volume, the cubic feet of cooling air per horsepower that flows over our engine and its relation to the speed, the volume varies almost directly as the engine speed. We cannot afford to change this one way or the other. It just happens to work out that our engine cools nicely at 450 r.p.m., at 50 m.p.h., and it takes about 550 cu. ft. per hr. of cooling air; whereas, for higher speeds, on account of the variation in the torque and the like, it works out to be 0.9 to 1.0 cu. ft. per sec. per hp. At the higher speeds, we could use still less cooling air; but, at the lower speeds, we need the cooling air.

In answer to the question on brake mean-effective pressure as compared to the compression pressure, a brake mean-effective pressure of about 77 lb. per sq. in. gives a compression pressure of about 70 to 71 lb. per sq. in.

I have been told that almost all the cooling in the Knight engine had to take place through the head; and that the oil-films and the sleeves were not good mediums to pass heat through.

We have used cylinder-heads 2 in. thick with perfect satisfaction. We went down to 3/8-in. thickness of cylinder-head but, when the head is too thin, the two valves in the cylinder-heads do not have a uniform distribution around the valve-seats and this is apt to give trouble. Therefore, we went back to a 5/8-in. thickness for cylinder-heads, and we have no trouble.

With an aluminum piston, we found that the cylinder life before regrinding ran between 25,000 and 30,000 miles before we applied the dust separator. Using the dust separator, that figure of 30,000 miles should be increased to 50,000 miles.

ARTHUR H. HOLMES:—From the way Mr. Grimes' paper is written, it is reasonable to assume that it is his intention to encourage water-cooled engineers in the study and the investigation of air-cooling. Having this in mind, I suggest that Mr. Grimes differentiate clearly between those features of the car he describes that are essential to air-cooling and those that are used in its construction because the company thinks that they are proper and should be used whether the car had an air-cooled or a water-cooled engine.

As an illustration, the majority of the following items are not in ordinary use on water-cooled cars. A seven-bearing crankshaft; case-hardening of the crankshaft; a distributor oil-pump; the use of a special grade of oil; a double carbureter; a dust separator for air to the carbureter; an electric primer for starting; a temperature control on the intake-manifold; special pistons; and duralumin connecting-rods.

It seems to me that, if it is Mr. Grimes' desire to encourage interest in air-cooling, it would be wise to state definitely that the above special features of the car he represents are not used because they are necessary in connection with the air-cooling of an engine, but are simply features that his company believe are desirable with an air-cooled or water-cooled car. Certainly, in my experience, especially in some of the late developments that we have made we have proved it possible to build an air-cooled engine that is absolutely identical with a water-cooled engine in everything but the cooling system. For 2 years we have produced cars that will use satisfactorily any oil that a water-cooled engine will use, and use it with the same satisfaction that is secured with a water-cooled engine. In other words, the better the grade of oil is, the longer the life of the engine will be, but the question of a high flash-point or a low-carbon oil is no more important to an air-cooled than to a water-cooled engine. We have used a standard carbureter and a standard manifold with a hot-spot, and have obtained results comparable with those obtained in water-cooled cars.

We have been able to run an air-cooled engine at full load on the block without any external cooling system, ever since we used the aeroduct method of air-cooling, and we have used it for a little over 2 years, but I believe we are not able to do this at as high a speed as Mr. Grimes mentions. We have never actually tried it at more than 1500 r.p.m. of the engine but, up to that speed, it is perfectly practicable to operate at full power for any ordinary period. We have run up to 4 or 5-hr. tests and, at no time during these tests, did we even cool the oil by any external means. I judge that the amount of air passing by our cylinders is practically the same as the amount Mr. Grimes states as passing by the cylinders of the car he describes, but I am of the opinion that the power consumed is a little more than he mentions.

I think the big important point in connection with air-cooling that engineers must overcome before the use of air-cooled engines is extended to any great extent is the cost of construction. My judgment is that every air-cooled engine that has ever been produced so far has cost considerably more than the water-cooled engine. I am frank to say that there is no basic reason for this that I can see, aside from casting the cylinders individually, and I am not sure that this is absolutely necessary.

The impression could be created by Mr. Grimes' paper that the cost of the air-cooled engine in question is very high on account of the different special features that I have mentioned. Perhaps it would be well to state that, in a four-cylinder engine we have developed and got ready for production but have not yet started to build, the cost will be but little more than that of a water-cooled engine produced in the same volume. There undoubtedly will be a 10-per cent difference. There is absolutely nothing about this four-cylinder engine that is different from a water-cooled engine of the same size and construction, except the air-cooling and its effect on the cylinders. I think this is a very important point to have the water-cooled engineers understand. This four-cylinder engine is the best performing air-cooled engine I have ever used.

its safety and its economy are especially good and, probably because of the simplicity of the structure, its reliability is equal to that of the best automobile practice of the day. Air-cooling should mean simplicity. I believe Mr. Holmes is just as anxious as I am that the water-cooled engineers should not get the impression that air-cooling involves a large number of special constructions that would interfere with simplicity.

Mr. Chilton—I am pleased to agree with Mr. Holmes regarding the suggestion that the great number of almost unusual refinements found in the Franklin products are not found in the water-cooled cars. At the same time I wish to call your attention to the fact that the exhibits at the Automobile Show this year would indicate the adaptability of a seven-bearing crankshaft, the use of a dust separator and an electric primer for starting. I am inclined to predict that more of those features that are now found only in our product will be adopted by the other manufacturers which in itself will be ample proof that these features are not essential to the success of air-cooling.

It has been the policy of the Franklin organization to cooperate with the owners especially in the question of oils to assure them the greatest satisfaction from the use of their car for every dollar expended for lubrication.

A number of my friends who are still using water-cooled cars have assured me that they have been well paid for their casual investigation of the Franklin products since it taught them the value of a good oil to their car. I wish to assure Mr. Holmes that the horsepower mentioned for moving our cooling air is correct to the best of our knowledge and belief. I might say to him that whereas he might not have felt justified in running his engine more than 1500 r.p.m. at open-throttle on the block, that I have just completed a very interesting little run on one of our engines that to the casual observer would be identical in every respect to our production and that I operated this engine with full throttle at 2500 r.p.m. for 1 2 hr. The room temperature was 90 deg. fahr., the cylinder-head temperature 254 deg. fahr. and the power developed at the end of the run was 33 hp. We maintained a stream of water on the under part of the oil-pan during this run which prevented the oil temperature from exceeding 150 deg. fahr. Otherwise the engine was cooled naturally by itself with the production fan.

COORDINATION OF MOTOR-TRUCK AND RAILROAD TRANSPORTATION

(*Concluded from p. 124*)

fact that this method seriously delays the traffic, and on the belief that the service is more expensive than dray or truck service. The remedy for this practice lies with the Interstate Commerce Commission, who should be petitioned to require the railroads either to discontinue performing a service of this character or to charge for it a rate commensurate with its cost.

A reason urged for retaining the trap-car service by those enjoying it is that it enables them to get better terms from draymen; that without it they would be at the mercy of the draymen. This implies that those who are without track location are mulcted by the draymen. This can hardly be the case.

Highway-Transportation Brains

I have tried to point out what seems to me to be the proper field for the motor truck and, in a general way, to indicate the necessity for further development along highway-transportation lines. It has been said that one of the reasons for the lack of development of highway transportation is the lack of properly organized highway-transportation companies, which should be in a position to operate over the highways along the same general lines as other forms of transportation. It has been said also that the lack of these organized companies is due in part to the lack of finances and to their not having the confidence of the public in the particular class of work they are trying to perform. This is true only in part. I believe that the lack of highway transportation is due principally to the lack of organized highway-transportation brains.

Motor-truck builders should undertake to cooperate closely with motor-truck operators. The motor-truck builders' responsibility should not end when sales of their equipment are made. I believe that in the engineering forces now employed by motor-truck builders there are many men who should use their engineering experience along the lines of highway transportation.

I am of the opinion that it would be to the advantage of the railroads of the Country to include in their organizations men who have had experience in building and properly using motor trucks. The railroads, to their advantage, should arrange for a more liberal mixing of commercial and railroad brains. I believe that one of the causes that has had much to do with the present dissatisfaction on the part of the public is the fact that the carriers are trying to solve commercial problems with railroad brains. It is difficult for the average railroad man, who is trained along railroad lines, to view the problems of transportation along the same broad lines as does the man who has had a commercial training. A great many of our misunderstandings would disappear if the carriers would use more liberally the services of the commercially trained man. We shall not be able to secure the best results from our railroads until the commercial and the railroad brains of the Country get together.

Motor-truck builders might also to their advantage include in their organizations terminal engineers, who, with the experience gained while in the service of the rail carriers, should be able to teach the motor-truck builders some of the proper uses of the vehicle.

The public also will require further education along highway lines. Only when the railroad and the highway are properly coordinated will each find its proper place in the economic transportation problems of the Country. The proper understanding of the "field" of the various transportation agencies is vital, but in determining this field each form of transportation should bear its proper responsibilities and charges. No one class of common carrier should be subsidized by the Federal Government or the States to the disadvantage of the other competing agencies. Only by a mutual understanding of their proper relations can the good of the public as a whole be advanced. The encouraging of active and forced competition would in the end be destructive.

One Hundred Ton-Miles Per Gallon

By J. B. Fisher[1]

Mid-West Section Paper *Illustrated with* Charts and Diagrams

THE two-fold purpose of the tests described was to acquire as many data as possible regarding the peculiar requirements of motorbuses, as viewed from the standpoint of power requirements and fuel economy, and to analyze the discrepancy found so often between the performance of an engine on the test block and the fuel economy obtained from the same engine under actual service conditions.

Following a general statement of conditions to be met, and an examination of the problems of the manufacturer as to why his choice of the various units and accessories is such a vital factor in fuel economy, the improvements accomplished are enumerated, together with the reasons and inclusive of the desirable and undesirable features of carbureter specification and miscellaneous factors.

The test equipment and methods are specified and discussed, the results obtained when using a steam cooling-system are presented and the general results are stated and commented upon.

EARLY in the spring of 1922, a series of tests was inaugurated at Waukesha, Wis., with a two-fold purpose in view. One was to acquire as many data as possible on the peculiar requirements of motorbuses, as viewed from the standpoint of power requirements and fuel economy; the other was to analyze the discrepancy that is found so often between the performance of an engine on the test block and the fuel economy obtained from the same engine under actual service conditions. Ideal conditions found in a laboratory do not prevail on the road but, with due allowance made for this, there is a wide gap between the ton-mileage of the conventional truck and what we felt could be obtained by a thorough analysis of the problem.

It has been stated that the potential energy in 1 gal. of gasoline is approximately 100,000,000 ft-lb. If we could use this energy with no thermal or mechanical losses, it would be sufficient to raise a 2000-lb. car vertically a distance of nearly 10 miles. Due to our crude methods of converting this energy into power, we are barely able to propel the same car twice this distance on the ground. If it were possible to eliminate the thermal losses from the engine, in spite of which we have reached our present figure of upward of 100 ton-miles, we would approach 400 ton-miles per gal. Obviously, it is not possible to eliminate such losses, but it is possible to locate the causes of many of them and, by reducing them to a minimum, to secure greater efficiency in the numerous units that exert such a pronounced influence upon fuel economy. As an example of this preventable waste, the fact was cited recently that if Ford cars gave as correspondingly good mileage as the Franklin, Dorris, Essex or several other well-known cars, the saving in fuel would be sufficient to purchase the Muscle Shoals plant every 18 days. The Ford case cited is perhaps extreme, but the factors that are responsible for this performance also affect the entire industry to a great degree.

To get a better understanding of this phase of the subject, let us examine the problems of the car or truck builder and why his choice of the various units and accessories is such a vital factor in fuel economy. After having determined the weight of his proposed job he decides upon an engine and, too often, he is influenced to choose too large an engine to meet the public demand for exceptional performance on direct gear; and this means relatively poor economy at the lower speeds at which the car will be operated 90 per cent of the time. As a rule, the foreign cars have much smaller engines and greater gear ratios than American cars, so that they can have the engine operating more often at a speed and a load that will give the best economy.

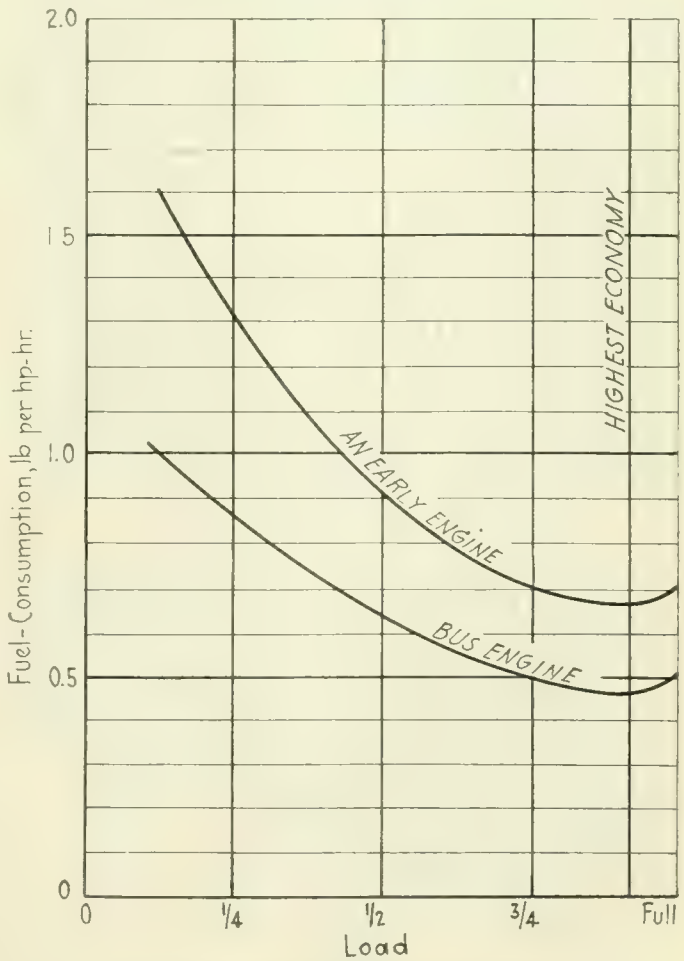


Fig. 1—Comparative Curves of the Fuel Consumption of an Engine Built a Few Years Ago and a Recent Motorbus Engine of Approximately the Same Displacement

[1] M.S.A.E.—Chief engineer, Waukesha Motor Co., Waukesha, Wis.

For several years we have been studying carefully the factors that would let us get not only better efficiency at full load but, what is still more desirable, better economy at the light engine loads under which the engine often is operated most of the time. The results of this work are indicated in Fig. 1, which shows a fuel-economy curve from one of our earlier engines and one from one of our late engines of about the same displacement. We have effected this improvement by

(1) Improved carburetion

(2) Use of higher water-jacket temperatures, without danger of hot spots, cutting down losses to cylinder jackets

(3) Higher compressions, made possible by better distribution, improved cylinder-heads and the use of special aluminum pistons

The increase in thermal efficiency made possible by the use of the improved cylinder-heads and special pistons is dealt with in H. L. Horning's paper[1] on the Effect of Compression on Detonation and Detonation Control, printed elsewhere in this issue of THE JOURNAL.

After the decision in regard to the engine comes that of the transmission and the rear axle. They must be chosen to insure that the engine works as near full load and at as an efficient speed as possible at all times for, the nearer it works to full load, the greater the output of power per pound of fuel will be. Too often, a rear axle is chosen to permit the truck to meet some extreme conditions, as in pulling out of excavations or climbing the severe grades along the water fronts of seaport and river cities. The result is that, when operated on a level on direct gear, the engine is running under part throttle. The better solution would be either an overgear in the transmission or additional speeds available that will allow the driver to keep the engine well loaded at all times. For similar reasons, if a truck is placed in intercity hauling-service, with loads in both directions, a certain rear-axle ratio would be suitable; but, if used in road work, with heavy loads in one direction and running empty on the return trip, the truck should have some type of over-gear to insure a high load-factor on the engine on the return trip. As an example of the better economy that can be secured by careful attention to these points, we found that changing the transmission at one stage of our tests to give a ratio of 0.787 to 1 in place of 1 to 1 gave an increase of 4.4 ton-miles, and replacing the original worm-drive axle with a double-reduction type gave a further increase of 5.8 ton-miles.

CARBURETER SPECIFICATIONS

While the choice of a carbureter is apt to have a vital effect on the fuel economy, there is another phase of the matter that is of still more importance; that is, the intelligent working out of the carbureter specifications to meet the specific demands of each installation. A carbureter setting that gives excellent results on an engine of a given displacement on a certain make of car is apt to give discouraging results on almost a duplicate installation, due apparently to minor differences in the two jobs that are not considered ordinarily as related to the carbureter itself.

Carbureters are almost invariably set too rich, because of

(1) Cold weather

(2) Hills

(3) Low water-jacket temperatures

(4) Starting and warming-up period in cold weather

(5) Low compressions in the cylinders due to part-load running

The mixture-ratios that the carbureter delivers at different throttle positions have a vital effect on economy. We have types of carbureter that

(1) Start with a rich mixture and, as speed increases, give a leaner mixture at all higher speeds

(2) Give a rich starting mixture, decrease the mixture-ratio and increase it again slightly at very high speeds

(3) Give a rich starting mixture and do not reduce the mixture-ratio sufficiently at any higher speeds, but continue to furnish an over-rich mixture throughout the range of the carbureter

MISCELLANEOUS FACTORS

The size of venturi tubes, fuel jets and bleeders must be determined under actual road conditions to give the best results; and the carbureter construction must be such that there will be a minimum variation from the original settings throughout the life of the car. That is, the working parts of the carbureter must be proportioned liberally to provide the proper assurance against wear, with the resultant fuel leakage and air leaks. Air leaks around the throttle shaft mean that the mixture must be enriched to compensate for the air that leaks in, especially under nearly closed throttle. The exceptionally long throttle-shaft bearings on Fifth Avenue Coach Co. buses are an example of the precautions needed to guard against fuel wastage at this point.

As supporting our promise that the identical carbureter settings that give good performance on the test block will, with the proper coordination of all other units, give equally good results on the road, we might mention that the carbureter used in these tests, after about 5000 miles of operation, was placed on a similar engine on the test block. With no change in the settings or adjustments, it gave a fuel economy of 0.51 lb. per hp-hr. with the engine operating a 20-in. fan as under service conditions.

A radiator and a fan that will cool an engine at full load in hot weather will just as certainly keep the water temperature too cool in cold weather, unless exceptional precautions are taken to correct this condition. With too cool water-jackets, we have high friction losses at the pistons and the rings, poor vaporization, dilution and low thermal efficiency. The relation of the fan to the radiator is important because, if it is not located properly, the corners of the radiator will be practically dead as the fan may consume considerable power in churning the air in the shroud.

Vacuum tanks sometimes draw the fuel over on the suction line, or deliver the fuel too rapidly to the carbureter.

Hot-air stoves, air-cleaners and the like are sometimes too restricted and do not allow an engine to attain its full volumetric efficiency.

Too often a cheap spark-plug is chosen, one that is damaged easily and gives a weak spark; or, one that, due to its construction, produces a spark knock and causes the operator to run with the spark too late for the best economy.

It does not seem at first thought that the way in which an engine is suspended in a chassis would affect the fuel economy; but, if it is not mounted properly, the weaving of the frame may distort a crankcase in this manner enough to cause the main bearings to be thrown out of line and actually stall the engine.

[1] and [2]

A magneto may contribute its share toward poor economy by furnishing a weak spark or by faulty action of the breaker mechanism at high speeds cause more or less missing.

Large bodies produce excessive wind resistance and, as the wind resistance is controlled mainly by the frontal area, it is important to be able to transport the maximum tonnage with a minimum frontal area.

This by no means limits the list of items that affect the fuel economy, although it comprises the major items that are passed upon, or often passed over, by the manufacturer. The above points are not cited in a spirit of criticism, but merely to illustrate the opportunities that are present for securing better performance and efficiency by a careful analysis of the relation of the various units that comprise the completed product. It is also well to mention that these same problems face the manufacturer who makes all of his major units in his own shop, as well as the smaller truck or car assembler; in fact, instances of neglect to recognize and correct the foregoing points are fully as common in the product of an organization of this type as in that of the assembler. When the truck passes into the hands of the owner, other factors appear such as the kind of fuel and oil used, attention paid to engine and carbureter adjustments, chassis lubrication and the like.

In addition to general conditions that confront the truck builder there are many other problems that, while related more or less to some of the above items, can be improved materially by recognizing these facts when designing the engine. To afford a better understanding of some of these problems, a brief description of the equipment used in this test is included.

Test Equipment and Methods

The truck used had a 2½-ton Sterling chassis, equipped with a large enclosed body having a frontal area of about 40 sq. ft. This type of body was used to let us approximate the bus type of body, as we were interested in getting as close to the conditions of bus service as possible. The tires were of solid rubber 36 x 4 in. front and 38 x 7 in. rear. The initial runs were made with a worm-drive axle that was used up to the last week or two of the tests. The radiator was of fin tubular type with seven rows of tubes; the area of the radiator was 560 sq. in. and the depth of core 3⅝ in. The fan was a Waukesha Motor Co. 20-in. four-blade, having a 2-in. projected width of blade, and running at about one and one-half times the engine speed.

Two routes were used for the test work. One of 24.4 miles was used for runs that would represent intercity traffic and another of 3.7 miles through the city of Waukesha to represent city running. The city run was made at different times with 12, 24 and 36 stops per trip. The last figure represents, approximately, 10 stops per mile. The load also was varied, from the 8300-lb. weight of the truck alone to a total weight of 16,000 lb. This was for the purpose of determining the effect of the various loads on the fuel economy. Most of the testing was done at a speed of 12 m.p.h. in the city and 15 m.p.h. in the country. This was varied at times but only to establish certain relations between speed and economy. A total of 296 observed runs was made, covering a period of a little more than 7 months.

At the same time these tests were being run we had another one of our engineers engaged in similar work in the congested districts of New York City, getting data for the Waukesha tests and, in turn, testing a number of the features brought out by our test runs. In the congested districts of New York City where this work was done, the average speed was sometimes as low as 5 m.p.h. with as high as 22 stops per mile. This would impose a very light load on the engine, which means that it would be operating down in the range of light loads and low speeds and, therefore, of poor economy.

The engine used at the start, at Waukesha, was our type CU 4⅜ x 5¾-in. unit, having a displacement of 346 cu. in. The improved thermal and mechanical efficiency of this engine, as a result of the better distribution and vaporization, together with the better performance obtained by proper coordination of the other units on the truck, made it possible to cut the size of the cylinder blocks from 4⅜ in. to 4 in.

One of the first problems that we undertook was to see what could be done to improve the carburetion. Several types of carbureter were tried. A carbureter that raised our initial mileage of 4.7 miles per gal. or 19.6 ton-miles to 5.5 miles per gal. or 22.8 ton-miles was finally selected for the test program. The representatives of the company making the original carbureter furnished with the truck were present at later stages of the test and, after going into the problem carefully, brought their performance in line with the mileage obtained on the carbureter that had been substituted for it to let us get somewhat more flexible carbureter settings.

We had observed, early in the tests, considerable condensation taking place in the manifold at the junction of the riser and the horizontal portion of the intake-manifold. O. H. Ensign, of the Ensign Carbureter Co., devoted considerable time in the past toward correcting the condensation that takes place at the tee and at the bends in manifolds of the conventional type, such as is shown at the top in Fig. 2. As a result of similar tests, we had for 3 years been using manifolds with sharp corners,

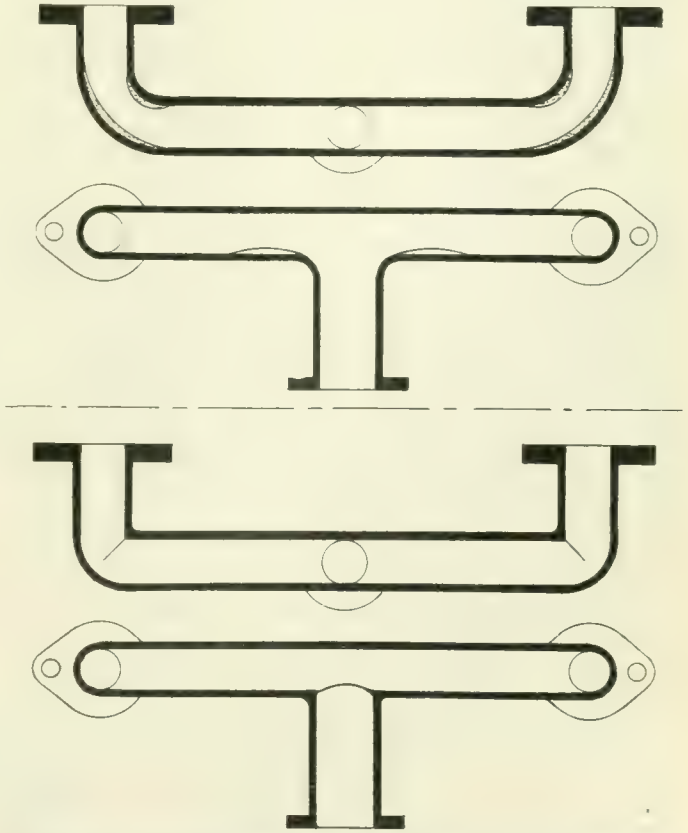
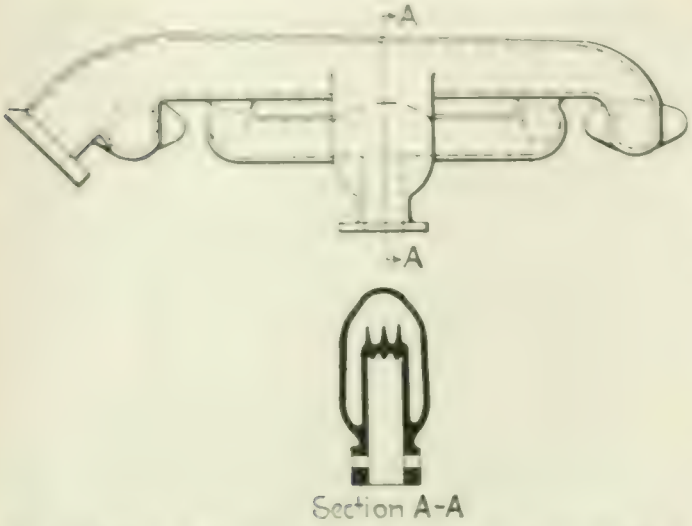


Fig. 2—The Conventional Type of Manifold (Above) and (Below) a Manifold with Sharp Corners that Has Been Used by the Waukesha Motor Co. for the Past 3 Years



[illegible] as shown at the bottom in Fig. 2. A small manifold with sharp bends may lessen the volumetric efficiency at high speeds, but the better carburetion and the improved performance at moderate speeds more than offset the slight loss in volumetric efficiency.

The tests described by W. S. James, of the Bureau of Standards, also showed the presence of large quantities of fuel at the tee in a Chalmers engine, when operated even under heavy loads, as indicative of similar conditions present in a great many other engines in popular use. He also showed in a glass manifold the tendency of the fuel to lie at this point, despite the application of heat to vaporize it. The tee was heated with two large blow-torches to a temperature of about 500 deg. fahr., and the fuel still lay at this point, riding on a layer of gas at times and rolling about the manifold much as water does on a very hot surface.

The customary procedure to overcome these conditions is some sort of hot-spot, an extreme type being shown in Fig. 3. Attention is directed to the distribution of heat at the tee and how it is carried under the inner corners of the tee where the condensation is greatest. Too many hot-spots direct the heat to an area above the riser and deliver practically no heat at the point where the condensed fuel is inclined to gather. The type of manifold illustrated in Fig. 3, although it corrects the conditions materially, does so at the cost of the volumetric efficiency as it often heats the air in the intake-manifold to 145 deg. fahr. The loss in brake horsepower entailed by the use of this manifold instead of a plain manifold at full load is about 12 to 15 per cent. The small surface available for vaporization and the very small fraction of time available for heating while the gas rushes past the hot-spot, also prevent the hot-spot from vaporizing the charge as thoroughly as we would desire.

To improve the conditions in the manifold without resorting to a hot-spot a small venturi was placed at the tee, which improved the distribution and lessened the condensation materially. Additional deflectors placed at the ends of the manifold increased our ton-mileage 8.8 ton-miles per gal. These venturis and deflectors were removed and check runs taken, and then they were replaced so that we could be satisfied thoroughly as to the reasons for the increase in mileage.

A special type of cylinder-head and aluminum pistons were employed. We found that, with the higher compression that we were eventually able to carry with these heads, our mileage was increased 17.5 ton-miles per gal. With the higher compression we had a considerable surplus of power, being able to operate the truck at 45 m.p.h. and accelerate it from a standing start to 15 m.p.h. in 9 sec. This meant that, over a great portion of the course, the engine was under part throttle and operating at relatively poor thermal efficiency; so, to raise the load-factor on the engine, the bore was decreased from $4\frac{3}{8}$ to 4 in. We still had ample power and gained 3.6 ton-miles, due to operating the 4-in.-bore engine at a higher load-factor than the $4\frac{3}{8}$-in.-bore engine.

We had been running for several weeks without a fan, to hold our water temperature as high as possible. As a result of the better mechanical efficiency at the higher temperature and the slight saving of the horsepower consumed by the fan, we gained 4.5 ton-miles per gal. The temperature along the test route at this time ran from 80 to 90 deg. fahr. Although we could do this nicely in hot weather, we knew that it would be difficult to do so in cold weather; therefore, we began to search for a system of temperature regulation that would maintain the maximum permissible jacket temperatures under widely varying weather conditions and especially at idling speeds and light loads.

Steam Cooling-System

A steam cooling-system was installed to permit better control of the water-jacket temperature and to aid in giving still better vaporization within the cylinders in cold weather. As we had been able to hold the water temperatures at from 205 to 210 deg. fahr. we did not anticipate better economy, especially as we had been running for a month without a fan; and the use of steam cooling meant using a fan with a little additional

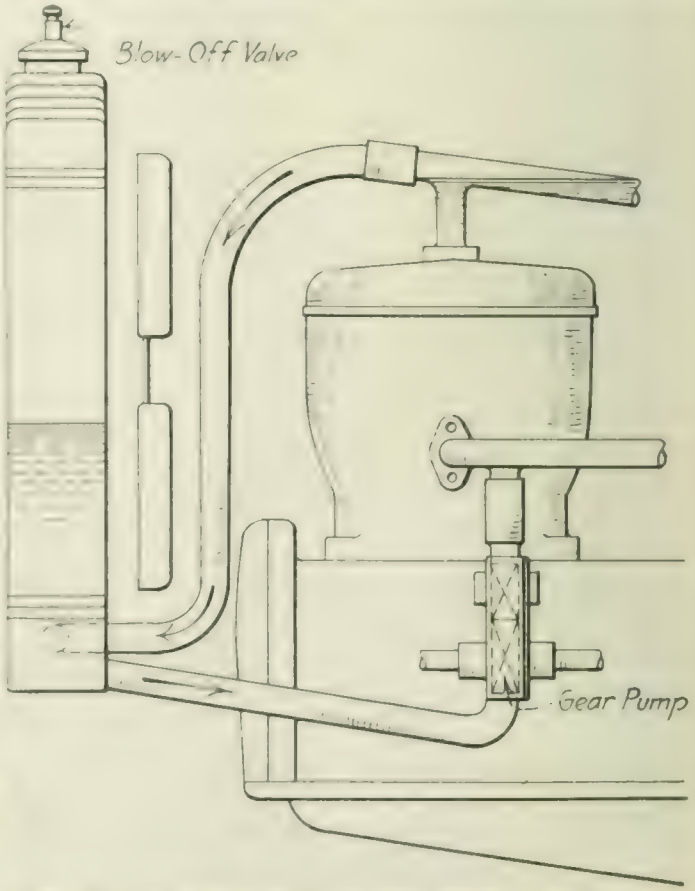


Fig. 4—A Diagram of the Rushmore Steam-Cooling System

power to run it. There was no appreciable change in the fuel economy at that time with a 60 to 70-deg. fahr. air temperature but, with the advent of cold weather, we have been able to appreciate the advantage of this system. With a temperature of 2 deg. fahr. below zero, it is possible to hold a jacket temperature of 190 deg. fahr. with the same radiator as was used in summer, idling 4 hr. on 1 gal. of gasoline. The truck has been operated on the road at zero temperature with excellent results, with the identical carbureter settings used in July and August.

With a conventional water-cooling system, about 100 B.t.u. per hp. is delivered to the cooling water per minute on an L-head type of engine; or, in our case, about 3500 B.t.u. per min. With a 20-deg. fahr. temperature-drop, this would mean the pump would have to circulate about 24 gal. per min. Our pumps on this model are made to handle a little in excess of this to take care of constrictions in the radiator such as are found often after several months of service, and also meet the high temperatures encountered in tropical countries. In the early days, with tank cooling, this problem was badly misunderstood; some tractor builders seemed to think that if a large enough tank was used it would cool the engine, losing sight of the fact that, with no facilities for radiating the heat carried into the tank, the water in it would eventually boil if the engine were kept under load long enough. The early pioneers in the tractor industry were not the only ones to lose sight of the fact; in one of the largest engineering enterprises completed within the present generation, insufficient means were taken to radiate the immense amount of energy introduced hourly into the system, with the same results as were encountered early in the automotive industry.

A diagram of the Rushmore steam-cooling system is reproduced in Fig. 4. The top water-outlet on the engine, instead of being connected to the top of the radiator, is carried down and enters the lower tank a few inches from the point where water enters the line leading to the pump. A header pipe lies in the bottom of the lower tank and many small holes are drilled in this pipe to distribute the steam better throughout the width of the radiator. A gear pump is used in place of an ordinary centrifugal pump, as the water level in the engine when running must be maintained high enough to cause the water to flow over the top water-pipe. The gear pump is also more positive in action than a centrifugal pump and forces the steam upward and out of the cylinder blocks as fast as it forms. With a centrifugal pump, the formation of steam around the exhaust-valves or the spark-plugs, when once it is allowed to start, causes such a commotion that the normal flow of water is interfered with seriously, and it may even force the water downward and back through the pump. The gear pump serves as a traffic officer in this instance, with but one command to the stream of water and steam: "Keep moving and leave by the top exit." The actual amount of water moved by the gear pump on a steam-cooled job is far less than with water cooling, often but 20 per cent as much. The reason for this is that the temperature drop, even with the inlet water at 190 deg. fahr., is far greater than in a water-cooled engine, as the outlet temperature may reach 230 deg. fahr. There is also a greater temperature rise in the air passing through the radiator, due to the higher temperature of the contents of the radiator than in a water-cooled job.

The upper portion of the radiator is not filled with water, but serves as a condenser. If a shop steam-line is connected to the bottom of an ordinary radiator and a powerful electric fan is placed back of it, no steam will pass out of the top. If the fan is set oscillating, the steam will rush out in a 2-in. stream the instant the air blast leaves the radiator and stop the moment the fan starts the airstream again. With outlet-water temperatures of 225 deg. fahr., no knocking or evidence of hot-spots was found, but the engine ran decidedly smoother than with water-cooling and outlet temperatures of say 190 deg. fahr. The cylinder walls were hotter and of a more uniform temperature with the steam cooling-system, and the large area presented to the incoming charge as the piston was about to rise on the compression stroke was many times greater than the surface one could secure in a hot-spot on the intake manifold. The time element was also much longer when vaporization was secured in the cylinder itself.

A block test conducted several years ago with a type of rotating valve showed an appreciable increase of power and it was decided to install a set on the experimental truck and check the results of the block test. The rotating valves on the city running gave us an increase of about 2 ton-miles per gal., but on the country run the increase was 11 ton-miles per gal. The varying results that a given change would show on the city and the country runs was one of the interesting phases of the various changes made throughout the tests. The removal of the valve rotators on a check run showed no change for 3 days, then the mileage started dropping back toward its previous figures, but promptly came back again to the same figures when the rotators were placed in service again.

General Results

Some runs were taken at the conclusion of the tests to determine the relative effect of operating with still heavier loads. Increasing the total weight to 8 tons gave 89.6 ton-miles per gal. on the city runs and 115.3 ton-miles per gal. on the intercity runs. To determine just what portion of our results were due to equipment and what portion should be credited to the driver's skill in the manipulation of the truck, we had runs made by three different men, none of whom were truck drivers or had ever driven this truck before. The average of these three men was 110 ton-miles per gal., showing that a relatively small percentage of the results was due to any especial care on the part of the driver. In fact, at all times we endeavored to operate the truck as it would be operated in the hands of an average driver, as we desired to establish figures that could be duplicated by any drivers of average ability with this equipment. [The discussion of this paper will be found on p. 148.]

Effect of Compression on Detonation and Detonation Control

By H. L. Horning[1]

Mid-West Section Paper *Illustrated with* Charts and Drawings

Since the detonation tendency of the fuel is the limiting factor in the development of power and the efficiency with which the fuel can be burned, the author considers this phase of the subject with the idea of laying down the principles on which better economy can be attained through higher compression. The subject is discussed in regard to the causes of detonation and the methods of controlling them because detonation limits the compression at which an engine can run.

The phenomenon of detonation is analyzed, the author's opinion being that increasing the temperature causes an increasing frequency of radiant-energy impulses and that, finally, it reaches a point where the frequency corresponds with the critical rate of the electrons that bind the elements together; thus, it breaks them asunder and then the velocity attains the highest rate possible in a gas of that density and temperature.

The causes of detonation are enumerated and the methods of control are explained, consideration being given also to hot-spots, cooling difficulties and turbulence as controlling factors. A statement is made of the actual compression pressures attained without detonation in road tests, and charts showing the horsepower developed and the fuel consumption are presented.

At present, gasoline is a drug on the market; however, the trend is toward scarcity. The huge stock dividends of the oil companies are an economic [illegible] of the struggle to meet the demand on national resources; nothing, therefore, is so important as economy in consumption. A high duty is imposed on the automotive industry to set its house in order by producing the most effective apparatus for the conversion of the fuel energy into useful work, consistent with the efficiency of the user and commercial considerations. The general chassis conditions affecting economy, which are almost always neglected, have been stated; but I wish to emphasize them because we often find that the most economical engines, when applied to a vehicle, give a lower miles-per-gallon performance than a poor engine, because the units are not coordinated. Since the detonation tendency of the fuel is the limiting factor in the efficiency with which it can be burned and the power developed, I have taken this phase of the subject with the idea of laying down the principles on which better economy can be attained through higher compression. Detonation limits the compression at which an engine can run and, therefore, we will discuss it in regard to its causes and the methods of controlling them.

For some 8 years American engineers have made an intensive study of detonation, or what is commonly called "pink," "ping" and "knock." A dull thud, which is presumed to be due to a shock in the combustion-chamber and is related only to the detonation because a detonation, if persistent, will end in preignition. But a detonation is a phenomenon related to that velocity of reaction which produces a sharp metallic sound from the cylinder-walls and, chemically speaking, is a reaction of such a high velocity that only part of the fuel enters into it; usually, the carbon fails to burn in the part of the mixture so affected. Physically speaking, when this knock occurs, the carbon particles glow and emit radiant energy. This is lost as useful energy and, further, it increases the temperature of the hottest spots in the cylinder, through the medium of carbon deposits. Thus, a vicious circle is established in which sections of the combustion-chamber become hotter under detonation. The cause and the effect unite to bring on the maximum effects, which are more violent detonation, preignition, further deposit of carbon and higher temperature, with the cycle repeating itself to the point where a heat balance is established temporarily, the gradual tendency being toward a hotter engine, until it is impossible to run the engine.

Many attempts to explain this phenomenon have been made considering the subject from the viewpoints of the chemist, the old school of physicists and the new school. My view is that increasing the temperature causes an increasing frequency of the radiant-energy impulses and that, finally, it reaches a point where the frequency corresponds with the critical rate of the electrons binding the elements together; thus, it breaks them asunder and then and there velocity attains the highest rate possible in a gas of that density and temperature.

Detonation Causes

We have held the opinion set forth by Thomas Midgley, Jr.[2] for some time; namely, that three factors control the weight of mixture consumed by the flame in a given time, in a uniform cross-section. These three factors are

(1) The reaction coefficient, which is characteristic of a fuel and is related entirely to the force diagram in which the electrons of the fuel are arranged
(2) Some power of the density of the fuel in the mixture
(3) Some power of the absolute temperature

Stated in every-day language, if a 53-deg. Baumé gasoline is tried, it probably will knock easily because it is composed of paraffines, which seem to be the least stable of all our common fuels; and, because it is so heavy, it will have large molecules that are also considered less stable than the lighter, simpler ones. The reaction coefficient, K, will then be very high. If a fuel of the Navy specification is used there will be less tendency to knock, but still it will be bad enough. With fuels of very high Baumé readings, the fuel will have less tendency to knock, due to its simpler structure. If olefines and naphthenes and aromatics are tried, the last being toluol,

xylol, benzol and their derivatives, they will be found to be more and more stable and will not knock. The only difference in these fuels is the decreasing tendency to knock, so far as we are concerned with the running of the engine; all other conditions are practically the same, which is due to the reaction coefficient of the fuel as a chemical. Alcohol is among the most stable of all fuels and benzol has been run, by W. S. James and S. W. Sparrow, in a Liberty single-cylinder engine at a compression-ratio of 14 to 1 at the Bureau of Standards without detonation, as against our common ratio of 4 to 1.

Under the effects of density, all are familiar with the fact that when the mixture is lean, the compression low and the throttle closed, the engine will not knock. If we open the throttle wide, the engine may not knock until a certain speed, usually about 600 r.p.m., is attained. The engine will knock the richer the mixture becomes, until it becomes over-rich; then, the surplus fuel acts like any diluent or anti-knock compound and subdues the knock, very much at the cost of fuel economy. So far as the density is concerned, the more fuel there is in the air, at or below the perfect mixture-ratio, and the more weight of mixture there is in a cubic inch, the greater the tendency to knock will be. Usually, this is merely manifested to the user by knocking when the throttle is open, at the speeds of maximum volumetric efficiency and high load. At a higher speed, where the restriction through the valves hinders the fuel charge from entering, the weight per cubic inch of charge is less. So far as the engine design is concerned, the ratio of the volume when the piston is down to the volume when the charge is compressed is the fixed condition which primarily establishes the density under all conditions. Several factors determine the density of the charge, which, when it attains a certain critical value with a given reaction coefficient and temperature, will cause detonation.

Because there are a great many factors aside from heat that establish the density, and since the compression-ratio is the most important factor in economy, we must, therefore, suppress all other factors as far as possible so that the compression-ratio may be as large as possible. The following conditions affect the factor of density and must be held as low as possible:

(1) *Mixture-Ratio.*—The lowest ratio possible is controlled in a single-cylinder engine by the mixture-ratio at the spark-plug that will ignite promptly. In a multiple-cylinder engine, it is controlled by a ratio such that the mixture in the cylinder that gets the least mixture will ignite. This means, with bad distribution, that it is impossible to get low economies

(2) *Valve Opening.*—This must be as small as possible, so as to give a high velocity through the orifice to aid vaporization. This is true also of intake-manifold area; it is also true of the carbureter venturi-size which, together with the valve timing and the intake-gas temperature, determine the volumetric efficiency of the engine and hence its actual gage compression. With all these factors suppressed and the mixture-ratio as low as is practicable, the highest possible compression-ratio can be used

Speed of course affects the volumetric efficiency or the weight of the charge entering and, to have a high torque over a considerable range, it is necessary to have such a high charge-weight at full throttle and at slower speeds that the density is higher than the temperature conditions warrant to avoid detonation. Thus, to avoid detonation over a short range of slow speeds, the compression-ratio usually is reduced unduly. With the mixture-ratio at a minimum, with the temperature condition a minimum and with all other density factors held down, the compression-ratio can be maximum. This is the condition of the maximum indicated economy with a given fuel.

Friction horsepower and the pumping losses vary with the speed, and these are the final conditions that determine the economies at various loads and speeds. Aside from these conditions, a leaky valve and piston-ring combination shows a decided loss in the actual compression in the average engine. We have found it possible to increase the actual gage-compression 6 lb. by a better combination of piston and ring, and a further improvement of 3 to 4 lb. on the gage was obtained by securing a better seating of the valves. From these improvements alone, economy is certain.

It is commonly known that the engine will knock when the combustion-chamber is hot or when the air or the mixture is heated unduly before it enters the cylinder. We thus have considered all the factors that control detonation in view of our every-day experiences. Scientifically stated, they are: first, the reaction coefficient, which is a function of the structure of the fuel; second, the density, which is the weight per unit volume at the time the spark jumps; and third, the absolute temperature of the fuel at the moment of ignition, which determines its maximum temperature at all points in the cylinder and, for our purpose, the temperature of the

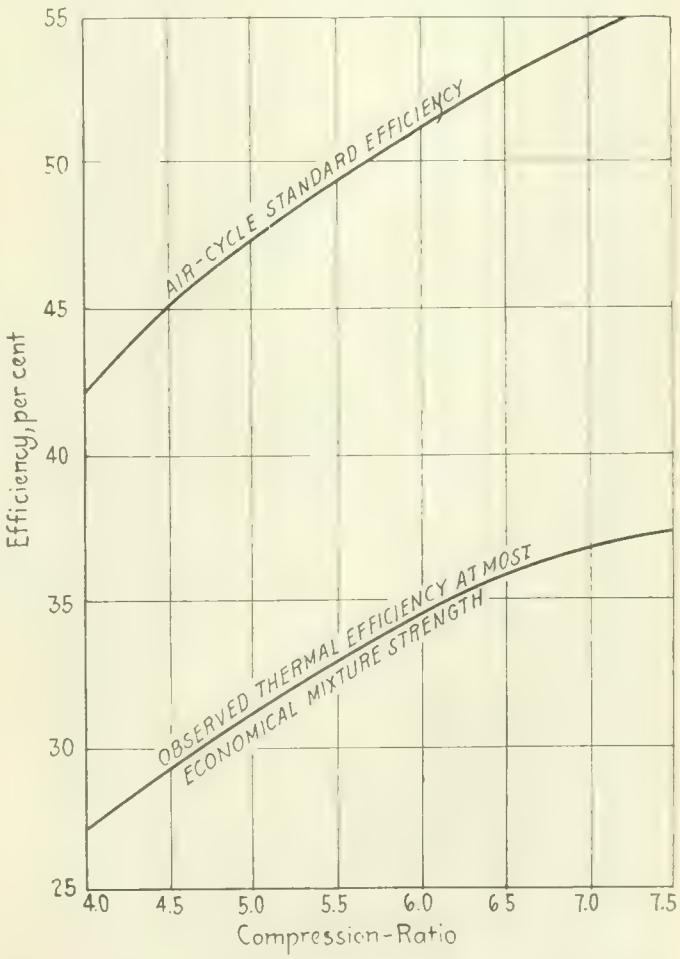
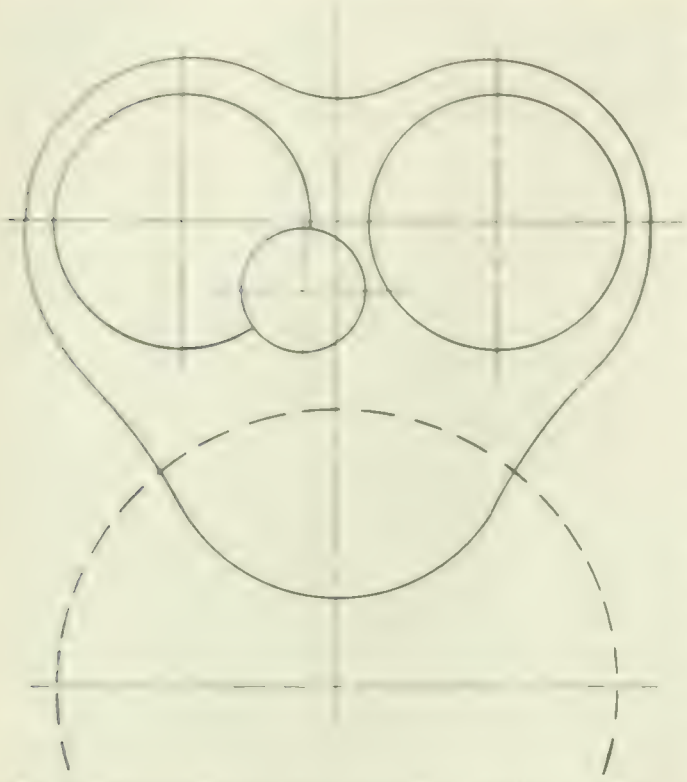


FIG 1—CURVES SHOWING THE RELATION BETWEEN THE COMPRESSION-RATIO OF AN ENGINE AND ITS EFFICIENCY FOR THE AIR-CYCLE STANDARD EFFICIENCY AND THE OBSERVED THERMAL EFFICIENCY AT THE MOST ECONOMICAL MIXTURE STRENGTH



[illegible] gas. It is the product of all these that [illegible] the critical state under which we have de-[illegible].

Detonation Control

We made the broad assumption that, to be of value in a wide field of usefulness and distribution, an engine would have to use a fuel of about Red-Crown gasoline characteristics, this fuel representing about the limit of what we would expect to burn effectively, considering the matter from a detonation and vaporization standpoint and that of our present knowledge. We assumed further that the greater part of the gasoline production was turned out by the large producers and was fairly uniform in composition; hence, that the reaction coefficient was practically a constant and could be eliminated from our [illegible]. All other fuels with better stability would give better results.

[illegible] the expansion-ratio determines one of the fac-[illegible] the density, and therefore the efficiency of any engine, it is important that we examine very thoroughly the controllable causes of detonation that limit compres-[illegible]. Midgley's accomplishment is in controlling the re-[illegible] and known as K in the equations used in [illegible]; reducing it increases the compres-[illegible] the temperature, or both. Our particular effort has [illegible] to discover what elements of design will subdue de-tonation effectively and thus allow an increase in com-[illegible] this is the fundamental necessity for high [illegible]. This brings us up to the relationship of [illegible] factors.

As is well known, the efficiency of a heat engine in-[illegible] with the expansion-ratio, sometimes called the compression-ratio or $R/1$, according to the upper curve [illegible] (Fig. 1. This is known as the air-cycle efficiency. It is not possible to attain this efficiency in practice, because the actual working fluid varies from the ideal air assumed in the equation. Various deviations from the true cycle, losses due to changing specific heat of the working fluid, dissociation of the products of combustion and losses by radiated heat to the walls of the combustion-chamber, cause a further loss. Experience has taught us that these losses bring the actual efficiencies down to those of the lower curve in Fig. 1. Therefore, our problem becomes the simple one of designing a practical engine in which the cumulative effect of the heat of compression, the temperature of the incoming charge, the temperature of the products of combustion left in the cylinder and the temperature of the hottest areas in the cylinder allow a compression such that the engine operates just short of detonation under the most adverse practical conditions. Simply stated, if we can suppress the charge temperatures a little, we can increase the compression considerably.

Considering the above categories, we are entirely helpless to influence the heat of compression, as this is a physical characteristic inseparable from the condition. We are able to control the temperature of the incoming charge within certain limitations imposed by the design of the manifold, the volatility of the fuel and the temperature of the atmosphere. This is covered by J. B. Fisher, in his paper[2] One Hundred Ton-Miles per Gallon, and is a very important matter. Most attempts at improving the vaporization of our fuels that are low in volatility have been confined largely to heating the fuel either by first heating the air or by hot-spots located in the intake passages so as to be in the path of the liquid fuel gathered on the walls. Whatever has been the method, it has been difficult if not impossible to keep the sensible temperatures down and, invariably, whenever sufficient to affect the vaporization in the manifold appreciably, the incoming charge is so high in temperature as to force the use of unfavorably low compressions. The loss in thermal efficiency in these cases invariably is greater, when the compression is adapted to the high mixture-temperature, than the gain in the carburetion efficiency. At the high speeds and with the high throttle-openings, engines suffer a loss of power due to the low volumetric-efficiency imposed by the high intake-temperatures that are associated with hot-spot designs.

The intake gas-temperatures have a great influence on the maximum temperature attained in the explosion, and this is one of the determining factors in establishing the compression-ratio that is possible without detonation. The product of some power of the density of the charge and the same power of the absolute temperature must be within some maximum limiting amount.

Experiments, which are discussed in Mr. Fisher's paper, have proved that, as between a hot-spot system with a cool combustion-chamber and with a cold intake mixture and a uniformly hot combustion-chamber, the latter is preferable, from both the vaporization standpoint and from the standpoint of efficiency, as it allows a valuable increase in the compression.

This brings us to the temperature of the products of combustion left in the cylinder. This is affected largely by the initial temperatures, the completeness of combustion at the time of closing the exhaust and the temperatures of the hot-spots.

Henry M. Crane, E. A. Johnston and others frequently have stated their belief that the most effective place to vaporize is in the cylinder. This has been very apparent in all tests where a wide variation of intake temperatures did not improve the carburetion efficiency.

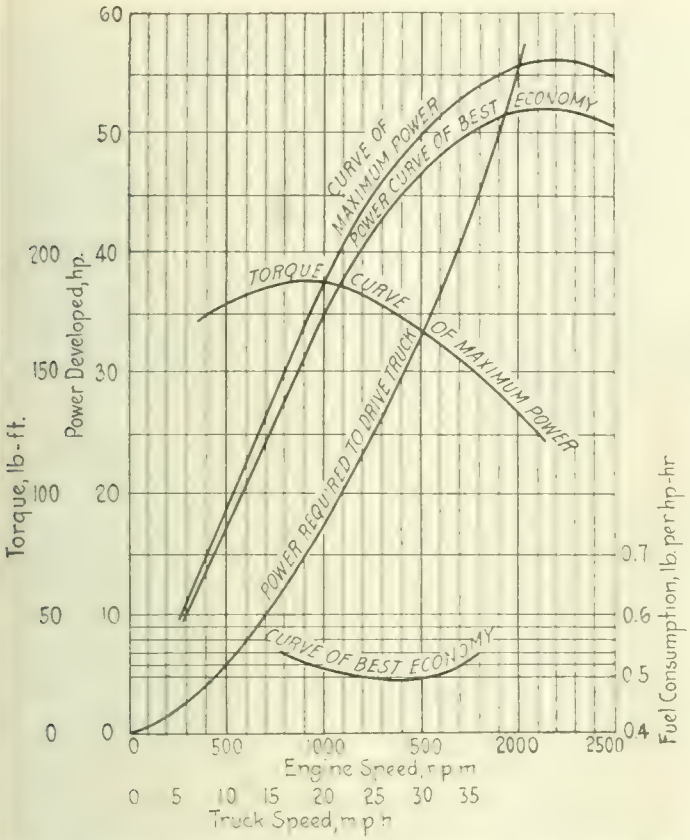


FIG. 3—CHART SHOWING THE POWER DEVELOPED, THE POWER REQUIRED TO DRIVE THE TRUCK AND THE FUEL ECONOMY OBTAINED

HOT-SPOTS AS CONTROL FACTORS

The hot-spots in the combustion-chamber are the most important conditions under the control of the engineer and offer an immense field for study and use. It has been pointed out many times before that the inherently high-temperature spots in a cylinder are as follows:

(1) First, the spark-plug electrodes, because of the adiabatic compression that surrounds the spark-plug during the entire duration of the explosion. Second, the unfavorable opportunity to cool its sections; that is, to cool the center electrode through the insulating material and the threaded sections of the spark-plug to the water-jacket, and due also to the distance of the central electrode from the cooling air. In connection with the spark-plug, we have found that there are a number of very good plugs that cool very well and give excellent account of themselves under practical conditions

(2) The exhaust-valve runs at red heat under high load, particularly if the seat is imperfect. It is through the seat that most of the heat is collected as well as dissipated. One of the most striking effects of turbulence is that, even though the exhaust-valve runs hot and has at times glowing particles on its surface, yet there may be and usually is no preignition because the gases are moving so rapidly over the surfaces of the valves. We have adopted a valve rotator so as to distribute the inequalities of the temperature and the surface and, by always seating in another place, reducing the permanent effects of local difficulties

(3) The temperature of the piston, particularly the piston center, the piston wall and the piston-ring temperatures, are very important elements in the operation of an engine. Mr. Fisher mentions these temperatures in his paper, in connection with their vaporizing effects and, as such, the piston presents the surface of the greatest value for that purpose, because of its area as well as its temperature. In connection with the piston, we have found it necessary to adopt aluminum pistons. We have followed the practice that was first adopted in aviation in this Country and in Europe: namely, a piston of the best alloy and ample head and ring sections to carry off the heat to and through the rings

As valuable as all these hot surfaces are as vaporizing elements, yet they often are too hot to effect vaporization because no liquid can spread on their surfaces at the temperature usually found. Any fuel that rests here assumes the spheroidal state and thus the vaporization is delayed greatly and is of questionable value. From a vaporization standpoint, therefore, it is of importance to hold these surfaces at a low relative temperature.

When it comes to the question of detonation, these surfaces are so disturbing as actually to control the question of the compression-ratio, other factors being the same. It is apparent that nothing short of the lowest possible temperatures of these parts, under the most severe conditions of running, is acceptable.

COOLING DIFFICULTIES

Aside from these well-known and well defined hot surfaces in the combustion-chamber, we must refer to some of the difficulties in cooling-water circulation that sometimes produce hot-spots. When there are pockets that give no easy escape of the rising water, or that cause

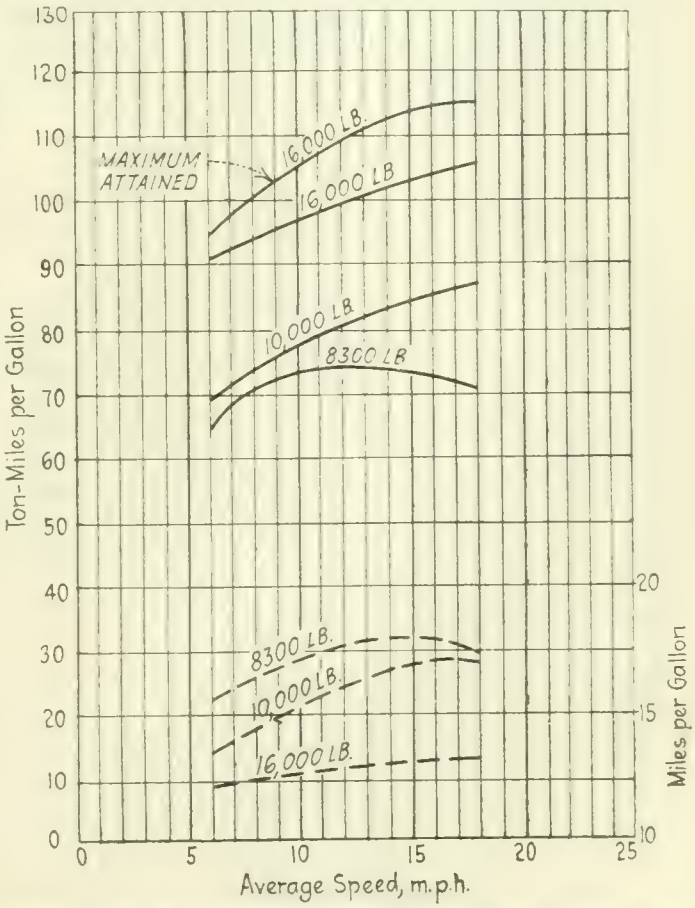


FIG. 4—FUEL-CONSUMPTION CURVES SHOWING THE MILEAGE AND THE TON-MILEAGE PER GALLON OF FUEL OBTAINED IN INTERCITY HAULING WITH THE TOTAL TRUCK WEIGHTS MARKED ON THE CURVES

steam to form from the lack of an unobstructed flow upward, then the water is forced from a hot-spot by belching steam and, when the water returns, the surface is so hot that it bounces off with little cooling effect. Thus a hot spot develops and spreads and can be the cause of detonation; often, it is most difficult to find because there are no such distinctive marks on the cylinder-wall as appear when a piston or an exhaust-valve is too hot.

Where the steam system of cooling is in use, there appears to be a more uniform temperature of all parts; the maximum temperatures are lower and the average is higher and more uniform. This is exactly what is favorable for high compression. Hot intake-gases and projections in the combustion-chamber are the curse of high compressions. The hot surfaces, presenting large areas to radiate heat, produce very sensitive volumes in the combustion-chamber which, when approached by the on-coming flame-crest, burn at the high velocities that characterize a detonation. Reducing the temperatures of these areas reduces the volume of these sections by drawing in the critical isothermal running over the hot surface, thus reducing the volume of mixture susceptible to detonation.

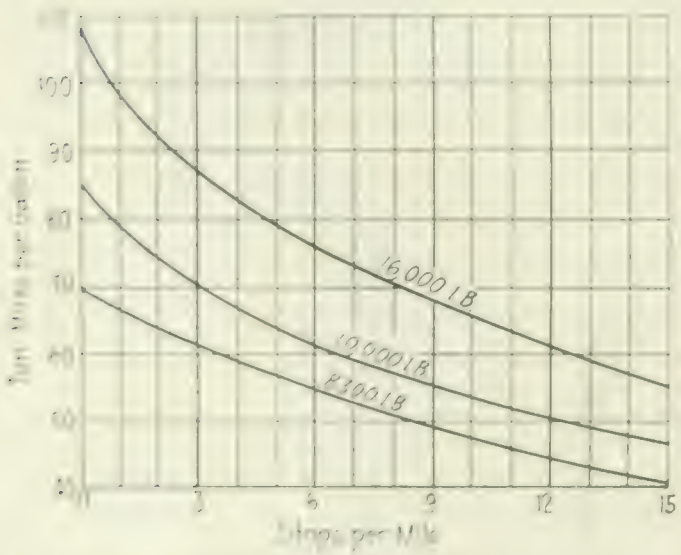
Turbulence

We have adopted a specially shaped modified Ricardo head of approximately the section shown in Fig. 2, which varies with the speed desired in a particular surface. In this, the spark-plug is located so that, as far as the large percentage of the mass of the mixture is concerned, it is in such a position as to be very close to all sections and the distances to the most remote sections are uniform.

So far as temperature is concerned, we can now mention all the factors that, if controlled, aid in establishing conditions permitting high compression.

(1) Cool intake gases
(2) Cool spark-plug
(3) Cool piston
(4) Cool exhaust-valves
(5) Relatively cool portions of combustion-chamber walls
(6) Turbulence

We have been able to reach a 5-to-1 compression-ratio



Curves

and a 104-lb. per sq. in. compression-pressure without detonation in a job on the road. With a water-cooling system we have been able to run in hot weather without a fan and with a regular pump. By the better control of the maximum temperature we have been able to run with lighter oils and to run longer; thus, by reducing the mechanical losses, we increase the lubricating-oil mileage as well as gasoline mileage. We have been able to make the miles per gallon and ton-miles per gallon indicated on the charts in Figs 3 to 5. Fig. 3 shows the horsepower, with the economy obtained and the power required; Fig. 4 shows the fuel consumption in miles per gallon and ton-miles per gallon for intercity work; and Fig. 5 shows the mileage per gallon on stop-and-start work in city traffic.

THE DISCUSSION

R. B. Hall:—When you use a steam radiator, do you also use any special kind of heated intake-manifold or just the plain manifold? In reference to the transmission and the rear axle, have you ever tested in regard to the heating of the oil to any extent in winter?

H. L. Horning:—We do not use a heated manifold with the steam system. Heating of the transmission and rear-axle oil actually does occur. It happened to me while driving here. When we started, I had difficulty in shifting to second gear; when we arrived, the gears shifted so easily that I thought I had lost my transmission oil. It took heat to do that. Heat is the energy that is driving the car and the energy which is in the shaft was converted into heat in the transmission and in the rear axle and then radiated; that heat goes out as absolutely lost energy. If you have these lubricants thin enough so that you do not need to heat them up to make them thin, mechanical losses are low. It should be remembered that viscosity is internal friction. Recently, in St. Louis, a test run between one-third and full speed showed a difference of from 3 to 8 hp. lost in the transmission itself. That was in warm weather.

J. G. Zimmerman:—It is evident that the spark-plug threads do not carry the heat through very well. Has an experiment been made using plugs of larger diameter with a correspondingly larger area to carry the heat away? How about allowing the incoming air from the carbureter or the manifold to strike the spark-plug to cool it or as a means of helping to cool it?

Mr. Horning:—A body will radiate a certain amount of heat per square inch of surface at a given temperature. In a spark-plug, a piston or a combustion-chamber, the thing to strive for is a large volume with a relatively small surface. The section that we use over the piston is just as thin as we can make it because we find that, whatever we sacrifice in the volume of mixture we eliminate from the effective pressure because that volume burns too late and constitutes one of the sacrifices that we must make to use the combination. Using the incoming air to cool the spark-plug is an excellent suggestion; some combustion-chambers depend entirely on that. One in particular is called the pent-roof head. It has a head like the one shown in Fig. 6. When the intake opens the cool charge impinges on the spark-plug, and it does tend to keep it cool.

C. E. Sargent:—These papers show the absolute necessity of looking after the small points. It seems that they have taken into consideration every little thing that helps in the efficiency and have taken care of it, which is a very good rule to follow when a high efficiency is desired. Mr. Horning stated that these little hot-spots

caused by the spark-plug and the valve and other things would prevent detonation if eliminated. How can they have any effect on detonation after inflammation has started? It seems to me that the elimination of the hot-spots would prevent premature ignition but that, after the inflammation has started, the hot-spots would have nothing to do with the detonation, the flame being very much hotter than the plugs themselves or any other hot-spot in the vicinity of the combustion-chamber.

MR. HORNING:—The particles of gas over a piston or any very hot sections are ready to detonate when the hot flames approach them. If you were to study piston temperatures and draw an isothermal line over it according to the temperatures of the piston, the isothermal line would bulge over the center. If we know the temperature above which we have detonation, then we have a volume of gas below this line which is sure to be involved in detonation under such conditions. The object in making a cool piston is to draw that isothermal line down so that we have a less volume of gas at critical temperatures. When the flame starting from the spark-plug approaches this volume, the ultra-violet rays reach out and set it off with a high velocity. The entire combustion-chamber is never involved in detonation. It is always some section like that, over the exhaust-valve or some uncooled spot in the water-jacket. In designing combustion-chambers, the spark-plug should be an equal distance from the hot-spots so that the flame will have traveled a distance that is a minimum to reach these points.

Surface-to-volume ratio is very important. Mr. Ricardo told me a year ago that he tested two engines of exactly the same size and exactly the same displacement. He found that there was absolutely no difference in horsepower and many other characteristics. Between a typical L-head engine and an overhead-valve engine at slower speeds, the heat loss was more at the moderate and at the higher speeds.

A MEMBER:—Mr. Horning made special mention of the importance of the engine accessories. Why do not the engine builders furnish the accessories that they deem advisable for a certain make of engine?

MR. HORNING:—The reason is that nobody will pay the engine builder a profit on them. Another reason is that the engine profits are so small that we cannot afford to send long distances to change defective accessories. There are so many kinds of accessories that the engine builder would be faced with an enormous inventory investment on which there was no profit.

A. Y. DODGE:—What is your analysis of the chief reason that you have been able to overcome carbonization? You laid stress on the importance of cooling the surface of the combustion-chamber; how do you keep this surface clean?

MR. HORNING:—The chief cause of carbonization is the carbon particles that glow during detonation but do not enter the combustion; when they get through glowing they drop dead, remain on the piston and all around it and cause trouble. If we prevent detonation, we can continue indefinitely without carbonization. If the piston is cool enough on the surface, the lubricating oil will not disintegrate. If we can keep the temperatures of the piston low, we can continue almost indefinitely without breaking down the oil or without this irregular combustion. Detonation is to a regular flame as a strike is to industry; a lot of energy is expended, but nothing but trouble is given back. Trouble is caused by the carbon deposited by detonation, and nothing is given in return for it.

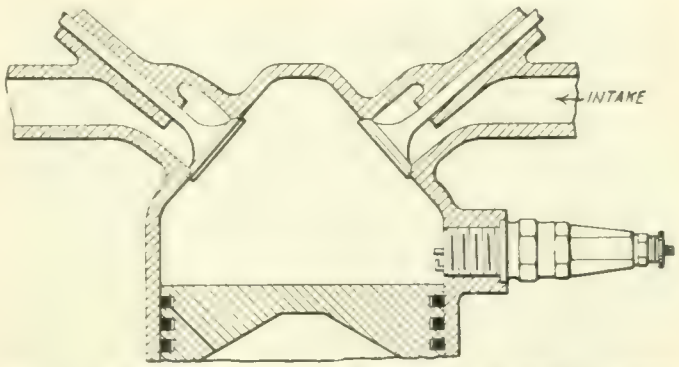


FIG. 6—A SO-CALLED PENT-ROOF TYPE OF COMBUSTION CHAMBER IN WHICH THE INCOMING AIR IS USED TO COOL THE SPARK-PLUG

W. S. HARLEY:—In speaking of piston-rings, Mr. Horning intimated that it is possible by design to get a better transmission of heat. To what sort of rings did he refer?

MR. HORNING:—It is not a matter relating to any particular ring but a matter of following the fundamentals. First, we must have enough metal in the head to conduct the heat entering the top of the piston to the surfaces of the ring on the groove side, which conducts the heat into the ring, and enough surface on the ring to conduct the heat over to the water-jacket through the oil film. We must have a balance between these. The important thing in piston and ring construction is the fit between them, because the heat path is through these surfaces.

A MEMBER:—Mr. Horning has given as the result of experiments that the heat would not pass through from one spark-plug screwed into another. The reason must be that there is an infinitesimal space between. On the other hand, he stated that the transmission of heat from the piston to the outside could come only through the piston-ring. There we have that space condition accentuated. Why should not heat pass through in one instance when it does in the other?

MR. HORNING:—You refer to the conduction of heat through a gas film between the exhaust-valve and the cylinder, where it was stated that a gas film is undesirable, as well as between the threads of a spark-plug and the wall into which it is screwed. In the spark-plug, unfortunately, we have a layer of gas between the threads, as is also the case between the exhaust-valve and the cylinder-wall. When we want a warm house we put an air space in the wall of the house. A thermos bottle is the best example of an air-gap. On the cylinder-wall we do not have a gaseous medium; we have a liquid medium which, we all know, is bad enough in regard to conducting heat. Lubricating oil is better than the gaseous medium, and that is the reason we have trouble in conducting heat away from the spark-plug and not from the piston to the cylinder-wall. Sometimes, when the piston is hot enough, the oil is so thin that the hot gases flow by and a vicious circle is established in which the piston gets hotter from the hot gases, the viscosity of the oil gets lower and more hot gases go by, and a gas gap and not a liquid gap prevents the escape of the piston heat; then the temperature rises until the engine stops from preignition.

Mr. Coleman, of the Madison Kipp Co., took one of our old engines that knocks badly, equipped it with his oiling system and stopped the knocking. The only reason the engine stopped knocking is that he succeeded in introducing an oil-film that had viscosity to it. He put in

first visions oil, one drop at a time, and stopped the hot gases from coming down; thus, the entire piston was kept cool.

A MEMBER:—What success has Mr. Horning had with the venturi mixing between the intake and the cylinder-head? How does he control the flow of the water through the water pump so as always to get a steaming condition in the cylinder?

MR. HORNING:—The effect is to cause better distribution. Venturis help in distribution. We found that the best method is to make an intake-manifold that is uniform in cross-section and small and keep the gas speeded-up. With respect to controlling the water supply in the steam system, we must admit ignorance about that. We just put it on and it worked.

A MEMBER:—Is the combustion space immediately over the piston just a mechanical clearance? What has Mr. Horning found regarding the durability of aluminum pistons?

MR. HORNING:—I have answered the question about the clearance. If you get the section about ¼ in. or 5 16 in. thick, the detonation is very bad; if we make the section thin, the detonation will not be so bad. Aluminum pistons having a proper amount of metal and properly cooled appear to resist wear equally as well as iron pistons do when the vaporization is fairly good.

AMERICAN AERONAUTICAL SAFETY CODE

THE project for establishing a safety code for aeronautics has during the past year taken concrete form and its formulation is in active progress. The work is being pursued according to the scheme of procedure of the American Engineering Standards Committee which in 1920 recognized the Bureau of Standards and the Society of Automotive Engineers as joint sponsors for the project according to the rules of that committee governing work of this character.

A Sectional Committee to handle the technical work was formed during 1921 and at a meeting in New York City on [illegible] 2, 1921, the permanent organization of this committee was effected, the officers being: Chairman, H. M. Crane, Society of Automotive Engineers; Vice-Chairman, Joseph S. Ames, National Advisory Committee for Aeronautics; Secretary, M. G. Lloyd, Bureau of Standards; Assistant Secretary, Arthur Halsted, Bureau of Standards. Five subcommittees were constituted, membership in which was subject to appointment by the Chairman and was not limited to members of the Sectional Committee. These subcommittees were appointed to deal respectively with the following:

(1) Airplane Structure, including design, construction and test
(2) Powerplants for Aircraft, including design, assembly and test
(3) Equipment and Maintenance of Airplanes in Service
(4) Lighter-than-Air Craft, including balloons, airships and parachutes
(5) Airdromes and Traffic Rules, including signals and qualifications for pilots

The Sectional Committee is composed of representatives of the following organizations:

Aero Club of America
Aeronautical Chamber of Commerce
American Society for Testing Materials
American Institute of Electrical Engineers
American Society of Mechanical Engineers
American Society of Safety Engineers
Bureau of Standards
Forest Service
Manufacturers Aircraft Association
National Aeronautic Association
National Advisory Committee for Aeronautics
National Automobile Chamber of Commerce
National Safety Council
Navy Department
Post Office Department
Rubber Association of America
Society of Automotive Engineers, Inc.
Underwriters' Laboratories, Inc.
United States Coast Guard
War Department
Weather Bureau

The work is intended as a cooperative research for the establishment of engineering safety standards in aeronautics, by which the relative merits or safety of aircraft, airdromes or their operation might be judged with uniformity by different individuals. The work was started with a synopsis of a safety code and preparatory draft made up from a study of rules and recommendations already in existence in aeronautical literature or compiled by various organizations for their own use. The subcommittees have studied and amplified this preparatory draft, modifying it to fit experience in practical aviation and supplementing it with material on subjects not already completely covered.

The American Aeronautical Safety Code will include various various parts as follows:

Introductory Part.—Scope and Nomenclature
Part 1.—Airplane Structure
Part 2.—Powerplants
Part 3.—Equipment and Maintenance of Airplanes
Part 4.—Signals
Part 5.—Airdromes and Airways
Part 6.—Traffic Rules
Part 7.—Qualifications for Pilots
Part 8.—Balloons
Part 9.—Airships
Part 10.—Parachutes

In the development of the code the broadest cooperation from the industry in general is desired and to secure this, parts of the safety code that are well advanced in the subcommittees are accepted as preliminary reports and copies circulated to persons who are sufficiently interested in the project to study and criticize them.

National uniformity in procedure and practice, where such is desirable, will undoubtedly be facilitated by this work and such uniformity can better be approached or established in the early stages of the art before diverse and conflicting local practices and laws become established.

The safety code can be used as a source of well considered information by agencies undertaking the establishment of airports and airways or commercial air services and will also be of assistance to the manufacturers of aircraft.

Three parts of the code, those relating to Airdromes and Airways, Balloons, and Airships, have been completed and submitted to the Sectional Committee, which has accepted them. These will be published in the near future and circulated among those interested in the development of aeronautics. They have not been adopted by the Sectional Committee and are subject to revision pending such adoption when all parts of the code are ready for consideration together. After adoption by the Sectional Committee, the code must be approved by the sponsor organizations before its promulgation.

In the Society the code will be submitted through the Aeronautic Division to the Standards Committee and the Society in accordance with regular Standards Committee procedure before its approval by the American Engineering Standards Committee as a Tentative American Standard.

Rear Axles for Trucks

By E. Favary[1]

Metropolitan Section Paper *Illustrated with* Photographs and Drawings[2]

THE five types of final drive now in use on motor vehicles are stated by the author to be (*a*) the chain-and-sprocket, (*b*) the bevel-gear, (*c*) the worm-gear, (*d*) the double-reduction and (*e*) the internal-gear. The advantages of each type as emphasized by its maker are presented and commented upon, and the same procedure is followed with reference to their disadvantages.

Following these comparisons of the different drives, which cover about the first third of the paper, the bearing loads and shaft stresses of typical semi-floating and full-floating axles are calculated for the conditions (*a*) maximum torque plus the normal radial load on the wheel, (*b*) the wheel locked and skidding forward when the brakes are applied and (*c*) the wheel skidding sidewise while the truck is moving. A tabulation of the results obtained from the mathematical calculations is included. The author concludes from these results that while the maximum shaft-stresses are practically the same in both designs, the shaft in the full-floating axle can be made lighter and that a higher factor of safety should be employed in the semi-floating axle since the bending stresses are continually reversed. As the bearing loads in the full-floating axle are considerably higher, a greater bending moment is imposed on the axle housing, thus increasing the production cost of this axle because of the necessity for heavier bearings and axle housing.

The last third of the paper is profusely illustrated with photographs and drawings of various types of rear axle. These include the rear axle of the Class B truck, as well as commercial examples of the worm drive, internal-gear-driven axles with load-carrying members of different sections, double-reduction axles and an example of a chain final-drive.

IN all motor vehicles a certain gear-reduction, termed the final drive, takes place between the propeller shaft and the rear wheels. There are five general types of final drive in use: (*a*) the chain and sprocket; (*b*) the bevel-gear drive, with either straight or spiral gears, as mostly used on passenger cars; (*c*) the worm-gear drive, which is now the most common type used on trucks; (*d*) the double-reduction rear axle, in which two reductions are made between the propeller-shaft and the rear axle; and (*e*) the internal-gear drive, in which the first reduction is accomplished by bevel gears in the center of the axle, and the second by internal gears in drums or rings attached to the wheels. Each of the various final drives has its adherents, claiming advantages for certain types over those of others. I will endeavor to cite the advantages and disadvantages of each type as put forward in the literature of the various makers.

Bevel-Gear and Chain Drives

In passenger cars the bevel-gear drive is employed almost universally, most companies using the spiral-bevel type on account of its greater silence in running and because it permits the employment of a smaller pinion. Since bevel gears are not, as a rule, practicable for reductions in excess of about 6 to 1, their use on trucks, except on the smaller models, is ordinarily out of the question, for here the final reductions vary from about 6½ to about 14, depending on the capacity of the motor truck and the truck speed.

The chain drive[3] on trucks is used on about 4 per cent[4] of the models manufactured. The chief objection to the use of chains is their exposure to dirt and grit, which in time causes excessive wear and noise. A number of attempts have been made to enclose the chains by covers of some kind, but they gave more or less trouble and were not entirely successful, for provision must be made in the cover for chain adjustment and for the relative lateral as well as the vertical movement of the sprocket centers on account of sidesway and spring flexure. Hence, today, most of the chain drives run with the chains exposed and by the employment of hardened chain-rollers, pins, bushings and links the wear and the noise are minimized.

Lack of lubrication is by far the most common reason for noisy chains. It is claimed that applying lubrication to the chains each day, which takes only a few minutes with a brush, results in greatly decreased noise and wear, and that with proper care and treatment chains will run from 40,000 to 50,000 miles. This figure is considered far too high by users of chain-driven trucks. The following are the principal advantages claimed for the chain drive over the other forms of final drive:

(1) Simplest in construction
(2) Will stand as much or more abuse than any other type
(3) Average total efficiency, including the losses in the jackshaft, is as high or higher than that of any other form of drive
(4) Increased losses due to worn chain and sprockets are very slight
(5) Easiest form of final drive to repair, as repairs can usually be made on the road with spare links
(6) Bevel and differential gears are carried on the sprung portion of the vehicle and are thus immune from road shocks
(7) A substantial load-carrying can be employed, which in the event of an accident will not damage the drive-shaft and the gears
(8) The differential gears and the drive-shaft can be made lighter than in most of the other types as the maximum torque is produced only at the rear wheels
(9) The universal-joints are arranged to run in line between the transmission and the engine, since both are attached rigidly to the chassis
(10) Offers the lowest unsprung weight, thus increasing the riding comfort

Some firms use the chain drive exclusively for their heavier models but give the purchaser the option of a chain drive or a double-reduction drive in the smaller

[1] M.S.A.E.—Consulting engineer, New York City.
[2] Copy for illustrations supplied by the McGraw-Hill Book Co., New York City.
[3] See Transactions, vol. 9, part 1, p. 223 and vol. 11, part 2, p. 324.
[4] See *Automotive Industries*, Feb. 16, 1922, p. 362.

...ster. The former offers a greater road-clearance than the live-axle type of drive and a much greater range of gear-ratio changes than any other type. In the Mack truck, for instance, gear-ratios can be made from 6½ to 1 to 14 to 1 without altering anything but the sprockets and perhaps adding or taking out a link or two of the chain.

In addition to greater wear and noise, chains will require more frequent repairing and renewing than the gears of the worm or bevel drives. When sprockets are worn until they are hooked, or until the true form has been destroyed and the teeth are slightly hooked at the ends of the driving side, they will cling to the chain as it leaves the sprocket and are then pulled away violently. It is claimed that this can be remedied by some forms of sprocket design. The chain drive is superior to the worm drive under heavy load and torque and only slightly less efficient than the worm under high speeds and light loads.

The Internal-Gear Drive

In the internal-gear-driven axle,[5] first a bevel reduction is provided between the propeller-shaft and the rear-axle, as in most passenger cars, and to obtain a further reduction at the end of the live axle near the wheel or in the hub small spur gears mesh with internally cut gears attached to the wheel.

One of the advantages claimed for the internal-gear-driven axle is great strength, since it permits the use of a solid, one-piece load-carrying member, usually a drop forging of I-section or a round axle made from bar stock. Sometimes the load-carrying member is flattened and shaped in the center to encompass the differential housing, while in some designs the live axle is within the load-carrying member. Other advantages are (*a*) this axle can be made lighter than the worm-gear type, since the jackshaft and the differential run at a lower torque than in the worm-drive axle, the great speed-reduction being made at the wheel, while the reduction at the bevel gears in the center of the axle is usually less than 2 to 1; (*b*) the internal spur-gears and pinions are mounted on fixed centers and require no adjustment; and (*c*) the cost is low, while the efficiency is high and fairly constant at all loads.

One of the serious problems with most of the internal-gear-driven axles is the proper lubrication of all the parts of the drive, although it is claimed by its sponsors that this drive can run with very little lubrication. The large diameter at the ring gear gives plenty of opportunity for the grease to leak out around the edges of the gears and onto the brake. However, some types run in a constant bath of oil, and the joint is not close to the large diameter of the ring gear, but nearer the center. Another objection against the internal gear is that it is more difficult to provide the double internal-brakes on the wheel. Even where the internal brake is used, considerable difficulty is experienced with the rise in the temperature due to the application of the brakes, which may cause the lubricant to melt or burn. At present the tendency is to use internal rather than external brakes, as the latter form is exposed to dust and grit. The internal gear, as usually constructed, cannot be made in the semi-floating construction, thereby eliminating the use of this design where the unsprung weights can be considerably reduced over those of the full-floating type.

Opponents of the internal-gear axle further claim that it has several fundamental defects. In most of the internal-gear types the load-carrying member is the dead axle, but in some a central live member is inside the dead member, one or more extra idler gears being inserted between the jackshaft pinions and the internal-gear rings in the wheel-hub. In all internal-gear axles the internal gear is carried by the wheel, or else in the wheel-hub between bearings, and all wheels will develop a certain amount of play, since they have to take the road shocks. They will therefore not continue to run perfectly true, and the gears will not maintain their exact relation. If the gears run out of alignment with each other, instead of on a line contact, the contact will take place only on a point, under which condition gears cannot wear well or run silently nor transmit the power efficiently, for the slight play in the wheel will cause them to rock to and fro slightly.

In most internal-gear axles the wheels are mounted on some form of dead axle while the jackshaft, running parallel, is either in front of or behind it and encased in a separate housing, whose only function is to retain the live member. If they do not retain their parallelism, there will be an additional tendency to throw the gears out of alignment. The torque reaction tends to revolve the jackshaft about the dead axle and is restrained from doing so only by the security of the end fastenings and by the rigidity of the dead axle against twisting. If the torque were always equal at both ends of the jackshaft, the twisting moments would be balanced, but since the traction of the two wheels is not absolutely equal, varying greatly at times, the torque stress on the axle is not equal on both ends. It is therefore claimed by opponents that this inequality of torque upsets the absolute parallelism of the two members, which will have a tendency to throw the pinions out of alignment with the internal gears.

In some constructions the load is carried on the dead axle, the jackshaft being perfectly free, not centrally supported; hence it is not deflected when the axle is deflected, and this will have a tendency to pull the gears out of line and cramp the pinion bearings. Sometimes means are provided to take care of the deflection by providing a universal-joint in the jackshaft, as in the rear axle of the De Dion-Bouton Co., and the Rochet-Schneider Co. of France. This, on the other hand, introduces a more complicated mechanism and a larger number of parts.

The type that has a separate dead axle weighs more for a given strength, since the larger outside dimensions of a hollow tube offer more strength with less weight; hence for the same factor of safety a solid axle is heavier than one of tubular construction. However, against the disadvantages enumerated is the fact that about 17 per cent of the models of trucks built in this Country employ the internal-gear drive and among its adherents are some of the well known companies.

The Worm-Drive Axle

The worm and wormgear are usually assembled in a unit and then attached to the axle housing.[6] In this axle the road shocks or stresses, except those coming through the driving-axle, do not tend to disturb the alignment of the wormgear. Provisions should be made for preventing the oil in the center of the housing from running out through the hubs. Oil-retainers are sometimes used on both the axle-shafts and the wheel-hubs for this purpose. A vent pipe in the rear-axle housing will assist in overcoming oil leaks. Adherents of this axle claim that its average efficiency is very high and that a truck equipped with a high ratio will coast quite freely.

The great advantages claimed for the wormgear axle are the perfect mechanical enclosure of the final drive

[5] See The Transmission, Vol. X, part 1, p. 167.
[6] See The Transmission, Vol. X, part 1, p. 165.

which is running in a bath of oil, and its practically noiseless operation. Even the wheel bearings are lubricated from the center housing, and when proper provisions are made there is no danger of the lubricant saturating the brakes. When the housing is filled with a suitable oil, the latter will last up to 5000 miles. Due to the perfect enclosure, dirt and grit are positively prevented from reaching the mechanism. Worm-gear axles are frequently equipped with double internal-brakes, which affords excellent protection against dirt and grit. It is claimed that wheel brakes are more satisfactory than propeller-shaft brakes, for with the latter the stresses in the drive-shafts and the gears are considerably greater than when wheel brakes are employed, the torque arising from the locking of the wheels of loaded trucks being much higher than that of the engine.

Other advantages claimed for the wormgear are (*a*) its great simplicity, it having the fewest number of parts; (*b*) it is possible to obtain any desired reduction with two pieces, the worm and the wormwheel; (*c*) it is possible to obtain an almost straight drive from the engine to the rear axle; and (*d*) its durability is very great. It is better to have the weight in the center of the axle than at the axle ends, for when one wheel rises, or hits an obstruction and is thrust upward, the upward acceleration in the center of the axle will be only one-half of that at the wheel; hence the stresses induced will be smaller, and the action will be more like that of a smaller unsprung weight than if the weight were at the wheels.

Opponents of the wormgear claim that (*a*) it is a highly efficient power-transmission gear only under certain conditions, for under a heavy torque a wormgear has a very low efficiency, while at high speed under light load, its efficiency is high; and (*b*) in coasting there is a certain amount of friction in the worm and the gear. Tests made by the International Motor Co. showed that trucks equipped with a worm drive did not coast as well as other types; hence, it is claimed, that even though the worm may be more efficient than the chain under certain conditions, its average efficiency throughout the range of conditions encountered in service is lower.

The most fragile part of the worm drive is the worm thrust-bearing, which takes the enormous thrust exerted by the worm. In some axles ball bearings are provided at this point; others are equipped with taper roller bearings. Since the worm must be carried on the top to obtain sufficient road clearance, the worm bearings can be lubricated only by the oil carried up or thrown up as the wormwheel rotates. When this runs at a low speed, sufficient oil is not always carried to the top. To provide sufficient lubrication special means, like oil troughs, are sometimes provided inside the wormwheel housing to catch the oil and lead it to the bearings. The worm drive is more expensive than other forms, but it is claimed that the maintenance cost is considerably less. When the pressure on the worm is not too high, the gears properly cut and the lubrication adequate, the film of oil is not squeezed out from between the surfaces, and there is very little friction. However, when the pressure is excessive and the oil is squeezed out, considerable friction exists and damage may result in a short time.

Another reason for rear-bearing failures is that the necessary play in the worm takes the form of a blow on the thrust-bearing whenever the clutch is thrown in or speed-changes are made and, while taper roller-bearings or ball bearings can withstand high pressures, they cannot withstand impact very well. Trouble with thrust-bearings may also be caused by improper clearances, which, under excessive strain or deflection, cause an increase in the temperature with a consequent elongation of the worm. In the worm drive the torque induces pressure on comparatively small surfaces of the teeth, which rub one on the other, while with toothed gears or chains and sprockets there is more of a rolling contact than pure friction.

Some manufacturers claim that torque-arms and radius-rods impose additional stresses on the worm; hence they advocate the Hotchkiss drive. With this a cushioning effect is imparted to the drive as the springs permit the axle to rock back slightly in starting, thereby reducing the pressure on the worm teeth when the car is first started and the torque is highest. It is also claimed that it permits the worm and the wheel to oscillate, thereby working more oil between the surfaces than is possible with a rigid drive. On the other hand, opponents of the Hotchkiss drive in connection with wormgears claim that they must put extra weight into springs when the latter are used to perform the functions of the torque and radius-rods, and wherever satisfactory results are obtained with the Hotchkiss drive the springs must have a greater factor of safety. I believe that the Hotchkiss drive when properly designed gives satisfaction, even though the springs are relied upon to perform more severe functions. While many objections are brought forward against the worm drive, 72 per cent of all the truck models manufactured in the United States use this type of final drive.

The Double-Reduction Drive

In the double-reduction rear-axle two reductions take place between the propeller-shaft and the live axle. The first reduction is by a pair of bevel gears and the second by a pair of spur gears, or vice versa. Instead of straight-bevel or spur-gear teeth, helical teeth can be employed.

The advantages claimed for this type are (*a*) simplicity of construction, in that only comparatively small bevel and spur gears are employed, which lend themselves easily to quantity production; (*b*) all the gears are perfectly enclosed and protected from dust and grit, and run in a bath of oil; (*c*) its average efficiency is as high as that of any other drive and is substantially constant under all speeds and loads; and (*d*) the gears will always remain in alignment and are silent in running.

The disadvantages cited against this drive are (*a*) an increased number of parts over the wormgear drive; (*b*) it is heavier than the internal-gear and the chain drive, since the live axle has to carry the entire torque; and (*c*) it is more costly to manufacture.

Semi-Floating Axles

Having discussed the various types of final drive, before analyzing actual examples of the different designs we will calculate the bearing loads and the shaft stresses of semi-floating and full-floating axles, for with this information we will be in a position to determine their merits and demerits.

To find the bearing loads and the shaft stresses in semi-floating rear-axles three distinct conditions must be considered. These are

(1) The maximum torque plus the normal radial load on the wheel
(2) The wheel locked and skidding forward when the brakes are applied
(3) The wheel skidding sidewise while the truck is running

For example, a certain high-grade truck axle has a maximum total reduction of 49.61; the maximum horse-

The diameter at the weakest point of the axle, which is at the inner bearing, is 2.4375 in. The polar section modulus at this point is 0.1963 times the cube of the diameter. Substituting these values in the formula for the shearing stress, we have

$$S = \frac{66{,}425}{[0.1963 \times (2.4375)^3]} = \frac{66{,}425}{2.84} = 23{,}400 \text{ lb. per sq. in.}$$

At the outer bearing the shaft is 4 in. in diameter and the stress due to torsion at this point calculated from the formula is approximately 5280 lb. per sq. in.

We will now consider the bearing loads and shaft stresses due to the bending moments. Under ordinary running conditions the radial load on each wheel is 9000 lb., the distance between the bearing centers is 25 in., and that between the outer bearing and the center of the wheel is 6 in. approximately as shown in Fig. 1. If H is the reaction or the radial load on the outer bearing, and H_1 that at the inner or the differential bearing, and if the radial load on the wheel is designated by P, then, taking moments about the outer bearing, we have $6P = 25H_1$, and $H_1 = \frac{6P}{25} = \frac{6 \times 9000}{25} = 2160$ lb. Taking moments about the inner bearing, $31P = 25H$, and $H = \frac{31P}{25} = \frac{31 \times 9000}{25} = 11{,}160$ lb. The bending moment in the shaft near, or 1 in. from, the inner bearing is 2160 lb., increasing toward the outer bearing, where it is $2160 \times 25 = 54{,}000$ lb-in.

The tensile and compressive stress S of a shaft is found from the formula

$$S = \frac{B}{Z}$$

where

B = the bending moment
S = the tensile and compressive stress of a shaft
Z = the section modulus

The section modulus, not the polar section modulus, of a round shaft is 0.098 times the cube of the diameter. Near the outer bearing of the shaft the diameter is 4 in. Substituting in the formula we have

$$S = \frac{54{,}000}{0.098 \times (4)^3} = \frac{54{,}000}{6.28} = 8600 \text{ lb. per sq. in.}$$

Near the inner bearing the diameter is 2.4375 in. and by substitution in the formula we find the stress equals 1523 lb. per sq. in.

To find the stress in a shaft subjected to torsion and bending stresses, we may make use of an equivalent twisting moment T_e, which would create the same stress in the shaft as that due to the combined twisting moment T and the bending moment B and is equal to the square root of the sum of their squares. Near the inner bearing $T_e = \sqrt{[(2160)^2 + (66{,}425)^2]} = 66{,}500$ lb-in. approximately almost the same as that found for the twisting moment only. At the outer bearing

$T_e = \sqrt{[(54{,}000)^2 + (66{,}425)^2]} = 85{,}000$ lb-in. approximately

The stress in the shaft at the outer bearing is therefore

$$S = \frac{T_e}{Z} = \frac{85{,}000}{12.56} = 6570 \text{ lb. per sq. in. approximately}$$

While at the inner bearing $S = \frac{66{,}500}{2.84} = 23{,}400$ lb. per sq. in. approximately, showing that the stress in the shaft is much greater near the inner bearing.

The material used for this shaft is S.A.E. Steel No. 2340, which, if heat-treated to a Brinell hardness of 335, or a scleroscope hardness of 51, has a tensile-strength of 175,000 lb. per sq. in. and an elastic-limit of 150,000 lb. per sq. in., according to the S.A.E. HANDBOOK. The shearing strength of steel is approximately 85 per cent of its tensile-strength or $175{,}000 \times 0.85 = 149{,}000$ lb. per sq. in., while the transverse elastic-limit or the elastic-limit in shear is approximately 35 per cent of its ultimate shearing-strength, and this should be considered when finding the factor of safety. Therefore, the elastic-limit in shear equals $149{,}000 \times 0.35 = 52{,}150$ lb. per sq. in. approximately. Very few data seem to be available as to the elastic-limit in shear of various steels. Hence, at the weakest portion of the shaft the factor of safety is $52{,}150 \div 23{,}400 = 2.23$ approximately under normal conditions, when running in low gear.

Next, we will investigate the bearing loads and shaft stresses when the brakes are applied and the wheel is locked and sliding forward. In this case there is a horizontal force at the periphery of the wheel equal to the vertical or normal load of 9000 lb. resting on it multiplied by the coefficient of friction 0.6, as was mentioned before, or 5400 lb. The two forces, the vertical and the horizontal, act at right angles to each other. The resultant radial load R on the wheel due to these two forces is equal to the square root of the sum of their squares or 10,500 lb. If we call the reactions or bearing pressures in the outer and inner bearings H, and H_1 respectively, by taking moments about the outer bearing we have $6R = 25H_1$, from which $H_1 = \frac{6R}{25} = \frac{6 \times 10{,}500}{25} = 2520$ lb. Taking moments about the inner bearing, we have $31R = 25H$; hence, $H = \frac{31 \times 10{,}500}{25} = 13{,}000$ lb. The bending moment near the inner bearing is 2520 lb-in., and near the outer bearing it is 25×2520 or $6 \times 10{,}500 = 63{,}000$ lb-in. Then, since $S = \frac{B}{Z}$, at the inner bearing $S = \frac{2520}{1.418} = 1770$ lb. per sq. in., and at the outer bearing $S = \frac{63{,}000}{6.28} = 10{,}000$ lb. per sq. in. approximately, the values for Z at the inner end of the shaft being 1.418 and at the outer end 6.28 as found before. It is seen, therefore, that under these conditions, with the wheels locked and sliding forward, the stresses in the shaft are very low, especially in view of the fact that the shaft is subjected to bending stresses only. The material is in tension and compression, and its elastic-limit is 150,000 lb. per sq. in.

We will now consider the bearing loads and shaft stresses resulting from skidding sidewise when turning a corner at a certain speed. Under these circumstances the centrifugal force F_c, which causes the rear of the

truck to skid, will equal the coefficient of friction, 0.6, multiplied by the total weight, $6W$, carried by the two rear wheels. In this case, therefore, $F_c = 0.6 \times 18{,}000 = 10{,}800$ lb.

Assuming that the center of gravity of the entire load on the rear wheels is located 45 in. from the ground, calling this distance h, that the total pressure between the two rear tires and the ground is designated by P, that P_o is the pressure on the outer wheel and P_i that on the inner wheel, when rounding a curve, that the tread, t, is taken as 56 in. and that the radius of the wheel, r, is 18 in., then, by taking moments about the point where the inner wheel touches the ground, we have

$$P_o \times t = (W \times 1.2t) + (F_c \times h)$$

or

$$P_o = 1.2W + [(F_c \times h) \div t]$$

Substituting the assumed numerical values, we obtain

$$\begin{aligned} P_o &= (18{,}000 \div 2) + [(10{,}800 \times 45) \div 56] \\ &= 9000 + 8700 \\ &= 17{,}700 \text{ lb.} \end{aligned}$$

The load on the inner wheel will be 9000 — 8700 or 300 lb.

In addition to the radial load, there is a thrust load L_t on the two wheels arising from the tendency to skid; this thrust load is equal to the centrifugal force F_c and is divided between the two rear wheels in proportion to their radial load. Hence, the thrust force on the outer rear-wheel between the tire and the ground $F_o = 0.6 \times P_o = 0.6 \times 17{,}700 = 10{,}600$ lb. Thus the total radial load on the outer wheel is 17,700 lb., and the side-thrust at the bottom of the wheel 10,600 lb. Taking moments about the inner bearing, we have

$$31P_o = 25H_1 + (r \times F_o)$$

or

$$H_1 = [31P_o - (r \times F_o)] \div 25$$

Substituting the corresponding numerical values for the various letters, we have

$$\begin{aligned} H_1 &= [(31 \times 17{,}700) - (18 \times 10{,}600)] \div 25 \\ &= 14{,}300 \text{ lb.} \end{aligned}$$

Taking moments about the outer bearing we have

$$\begin{aligned} 6P_o &= 25H_2 - (r \times F_o) \\ H_2 &= [6P_o - (r \times F_o)] \div 25 \\ &= [(6 \times 17{,}700) - (18 \times 10{,}600)] \div 25 \\ &= -3384 \text{ lb.} \end{aligned}$$

The result is a minus quantity as the bearing will carry the load on the top, while under normal running it will carry it at the bottom. It should be remembered that the outer bearing also has to carry a thrust load of 10,600 lb.

Knowing the bearing pressures or the reactions we can easily find the bending moments and the stresses in the shaft, as in the last example. The bending moment B near the inner bearing is 3384 lb-in. and near the outer bearing $25 \times 3384 = 84{,}600$ lb-in. approximately. In addition to the bending moment due to skidding, the twisting moment in the shaft due to the drive must be considered. Evidently the truck will have to be in the high gear to travel at the requisite speed to produce skidding; hence the torque will be much lower, but even if the truck were in the low gear, and the torque be 66,425 lb-in., the maximum stress in the shaft would be barely higher than under *straight forward* travel, when in the low gear. If the low-gear torque is added, the equivalent twisting moment near the inner bearing is practically the same as that found before, 66,500 lb-in., and the shearing stress equals 23,400 lb. per sq. in. Near the outer bearing the equivalent twisting moment has a value of approximately 107,000 lb-in., and the stress is 8550 lb. per sq. in. When skidding sidewise the torque is considerably lower in practice, for the truck would not skid unless it traveled in one of the higher-speed gears,

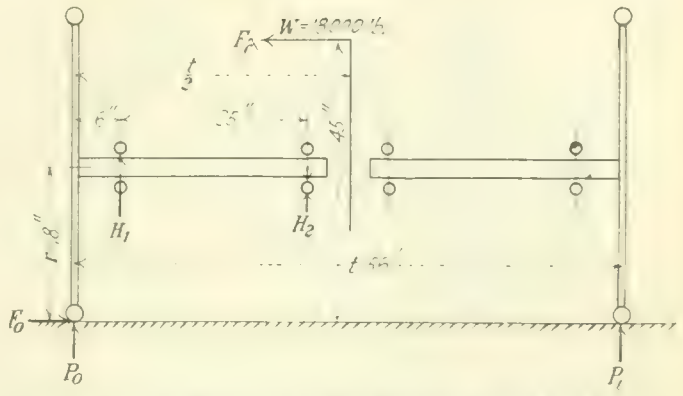


Fig. 1.—Diagram Illustrating the Bearing Loads and Shaft Stresses in a Semi-Floating Axle

unless the road surface were muddy or slippery, and in such event the coefficient of friction is considerably lower; hence the bending moment would be lower. The maximum stress in shear is therefore near the inner bearing on straight forward travel in the low gear and amounts to 23,400 lb. per sq. in.

Full-Floating Axles

The stresses in the shaft of a full-floating axle are purely torsional or shearing stresses, and if the engine power and gear reduction are as in the last example, the maximum torque will be as found before, 66,425 lb-in. in each axle-shaft. If the shaft dimensions are the same as those of the small end in the previous example, the maximum unit-stress for torsion in the shaft metal would be the same as that found before, 23,390 lb. per sq. in. In a full-floating axle the shaft dimensions are, as a rule, uniform, not tapered as in the semi-floating type, since the live axle is relieved of all bending moments by the wheel bearings.

The maximum radial load on the wheels, when the brake is applied and the wheels slide forward, is the resultant radial load due to the combined horizontal and vertical forces and is the same as found before, 10,500 lb. If the distance between the bearings is 7 in., as shown in Fig. 2, the inner bearing H_2 is 2½ in. from the wheel center, and the outer bearing H_1 4½ in., then, by taking moments about the outer bearing, we find $7H_2 = 4.5 \times$

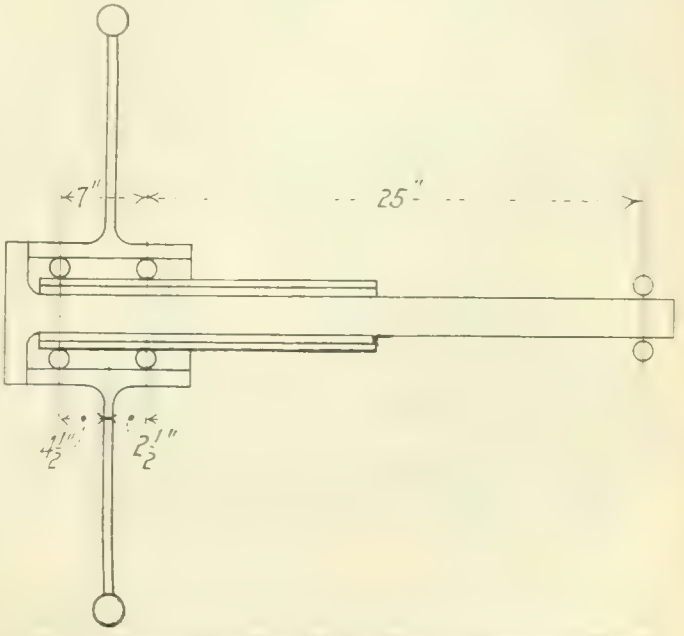


Fig. 2.—Diagram Illustrating the Bearing Loads and Shaft Stresses in a Full-Floating Axle

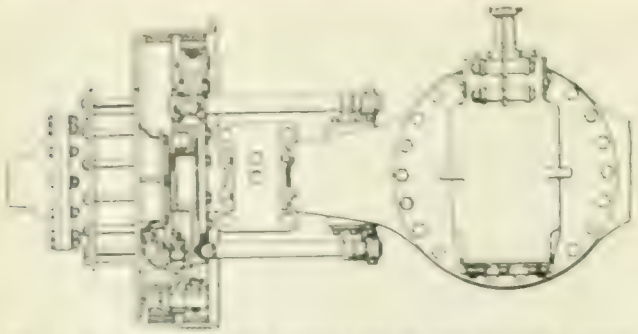


FIG. 3 [illegible] VIEW OF THE REAR AXLE FOR THE CLASS B TRUCK

10,600, and $H_1 = (4.5 \times 10{,}500) \div 7 = 6750$ lb.; the load on the outer bearing $H_1 = (2.5 \times 10{,}500) \div 7 = 3750$ lb.

When the wheels skid sidewise, the bearing loads on the outer wheel are considerably higher. If the portion of the centrifugal force F_c at the outer wheel that produces the skidding, and the radial load P_o are, as found before, 17,700 and 10,600 lb. respectively, then by the law of moments we obtain

$$7\,H_1 = 4.5\,P_o + 18\,F_c$$

hence

$$H_1 = [(4.5 \times 17{,}700) + (18 \times 10{,}600)] \div 7$$
$$= 38{,}700 \text{ lb.}$$

and

$$7\,H_2 = 18\,F_c - 2.5\,P_o$$

from which

$$H_2 = [(4.5 \times 17{,}700) - (18 \times 10{,}600)] \div 7$$
$$= -21{,}000 \text{ lb. approximately}$$

showing that on the outer bearing the load is reversed from its normal direction. In addition there is a thrust load of 10,600 lb. The results obtained are given in Table 1.

TABLE 1—COMPARISON OF STRESSES AND BEARING LOADS IN SEMI-FLOATING AND FULL-FLOATING AXLES

Type of Axle	Semi-Floating	Full-Floating
Maximum Stress, lb. per sq. in.		
Wheel	8,550	23,390
Axle at Differential	25,400	23,390
Maximum Bearing Load, lb.		
Outside of wheel	.....	—21,000
Inside of wheel	14,300	38,800
At the differential	—3,784	.....
Thrust load	10,600	10,600

From Table 1 we can judge that the maximum shaft stresses are practically the same in both designs, but the shaft in the full-floating axle can be made lighter and at less cost since the stress is uniform in the entire shaft and the shaft is relieved of all but torsional stresses. Furthermore, in the semi-floating axle, the bending

(See Transmission, on page 1, p. 16)

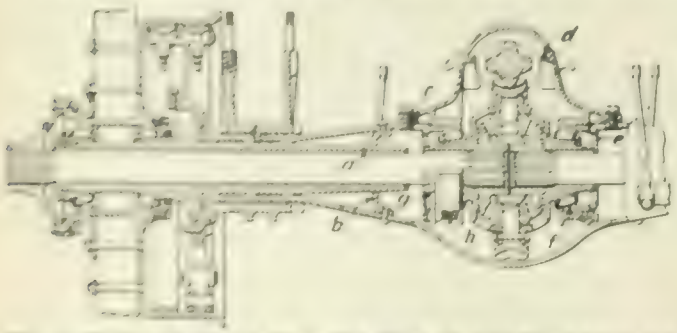


FIG. 4 [illegible] VIEW FROM THE REAR OF THE REAR AXLE FOR THE CLASS B TRUCK

stresses are continually reversed; therefore a higher factor of safety should be used. The bearing loads in the full-floating axle are considerably higher, which will impose a much greater bending moment on the axle housing. Hence the bearings and the axle housing must be made heavier and thus this axle will be more expensive to manufacture than the semi-floating axle.

PRACTICAL EXAMPLES OF WORM-DRIVEN TRUCK REAR-AXLES

Figs. 3 and 4 give a plan view and a sectional view, looking from the rear, of the "Class B" rear axle. The housing is of the Timken type, with a square section from the center bowl outward. The tubes *a* are pressed into place, a retaining screw being provided in addition.' These tubes extend to the bowl of the housing. The reinforcing plate *b* is riveted to the housing and fits snugly over the end of the tube. The wormgear wheel is mounted on the differential by 97 splines, 1/16 x 3/16 in. section and 15/16 in. long. The differential, the worm and wormgear are mounted on the differential carrier, which is piloted at the top of the housing as shown at *c*, Fig. 4. At *d* are oil-grooves to lead the oil to the worm bearings. The means used for holding the worm bearings are shown in Fig. 5. The gear adjustment is made by slotted and threaded rings behind the bearing differential-cups, as shown at *e* in the assembly, Fig. 4. The roller-bearing cups *f* are clamped to the upper main differential-carrier by caps *g*, which are held by 1-in. nickel-steel studs *h*. The entire unit can be removed from the housing without disturbing any adjustments. The six roller bearings in the wheels and at each side of the differential are all identical in size and thus interchangeable.

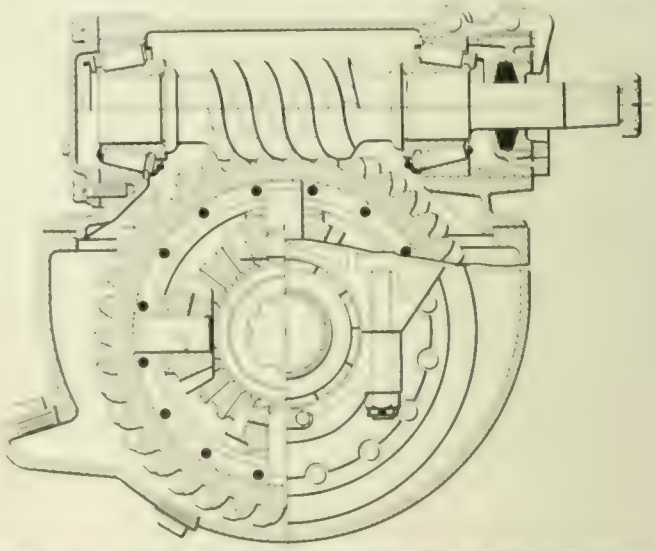


FIG. 5 DRAWING SHOWING THE ARRANGEMENT FOR HOLDING THE WORM BEARINGS

Fig. 6 shows a detail of the axle housing, which is a steel casting. The Government gave the manufacturers their choice of making this a steel casting as shown, or a steel stamping like that shown in Fig. 7.

Fig. 8 is the axle or drive-shaft made of chrome-nickel steel with a high carbon-content. At the weakest point the diameter is 2½ in. The axle is of the full-floating type; the radial load, as well as the lateral thrust, on the wheels is taken by taper roller-bearings, the shaft being only under torsional strain. The Class B truck is equipped with an engine having a torque of 2800 lb-in.; the ratio in the low gear of the transmission is 5.93 and in the rear axle 9.50; hence, the maximum ratio of re-

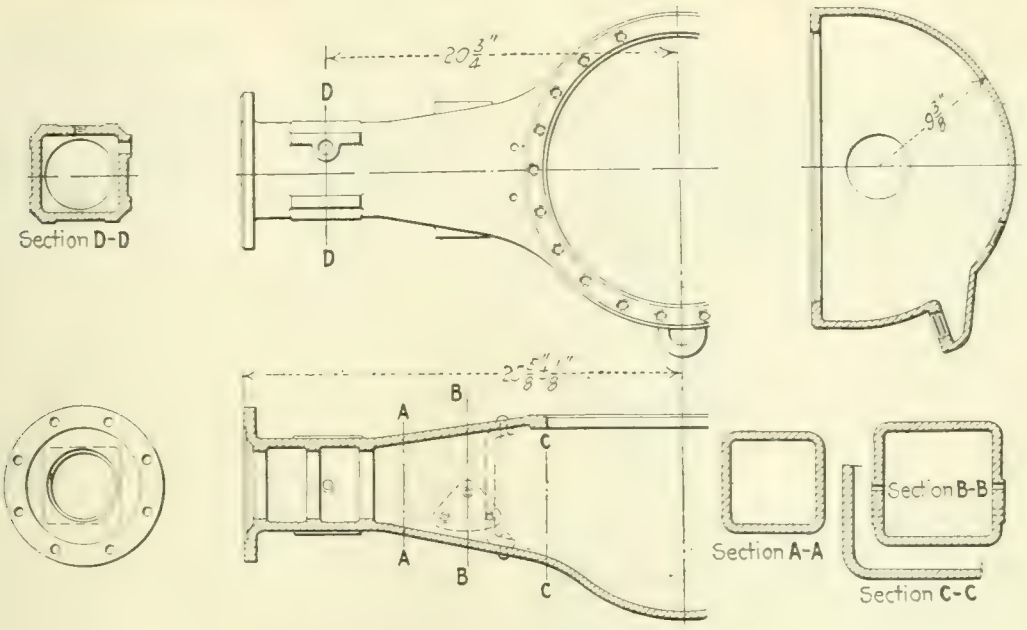


FIG. 6—DETAIL OF THE CAST STEEL AXLE HOUSING

duction is 56.3 to 1. The distance between the bearings in the rear wheel is approximately 5½ in.

Fig. 9 is the Sheldon rear-axle which is suitable for trucks of from 5 to 6-ton capacity. The maximum allowable load on the rear tires, including the weight of the truck and the pay-load, is 18,000 lb. The weight of this rear axle complete is approximately 2010 lb. In all the rear axles built by the Sheldon Axle & Spring Co. ball bearings are used for taking the worm thrust as well as the radial load of the worm, for which a number of advantages are claimed. The double-row bearing *i* at the rear carries the radial load as well as the thrust in both directions. It is claimed that with ball bearings no wedging is possible under thrust, whereas with taper roller-bearings such wedging exists. The front bearing *j* is free to move as the worm expands, due to a rise in temperature, which is occasioned by extra heavy work or lack of proper lubrication. No adjustments are necessary with ball bearings and, as the wormwheel and carrier are machined by very accurate jigs and fixtures, no adjustments are necessary in the first place. The semi-floating or fixed-hub type of axle is employed on all Sheldon axles; also the Hotchkiss drive.

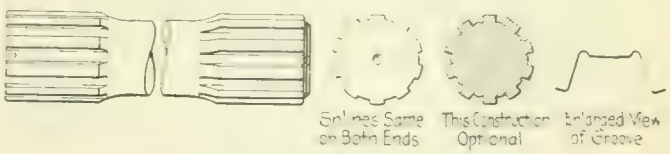


FIG. 8—AXLE OF THE CLASS B TRUCK

Fig. 10 shows the worm and wormwheel carrier, which can be removed from the axle housing as a unit complete with the worm, the wormgear and the differential. The lower section of the wormwheel runs in a bath of oil in

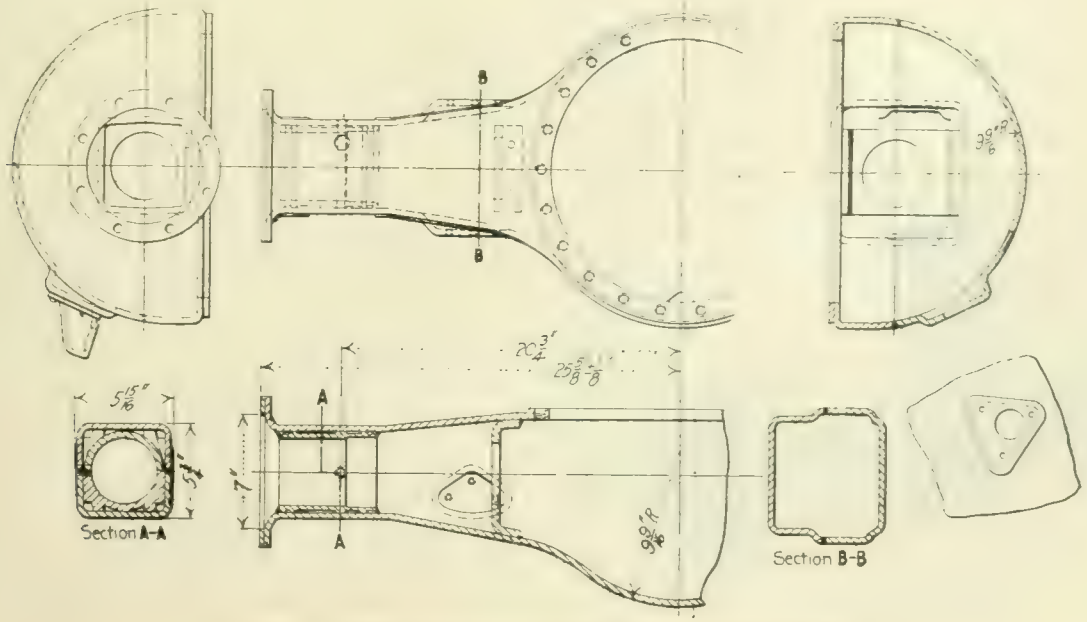


FIG. 7—DETAIL OF THE AXLE HOUSING STAMPED FROM STEEL

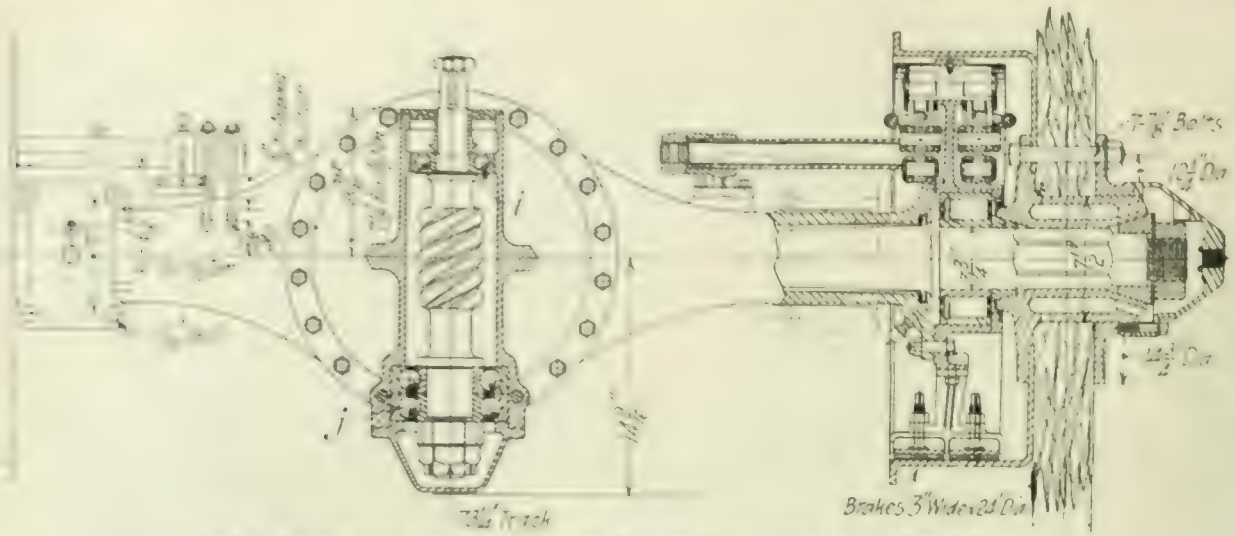


FIG. 9 REAR-AXLE ASSEMBLY FOR TRUCKS HAVING A CAPACITY OF FROM 5 TO 6 TONS

the end of the axle housing, and as the wormwheel rotates all the bearings and the worm and wormwheel are lubricated by the splash. The only other parts needing lubrication in the entire rear-axle are the brake rocker-shafts and the wheel bearings, and these are lubricated by oil-cups provided at these points.

The lower part of Fig. 11 is a detail of the axle shaft, made of S.A.E. No. 2340 heat-treated steel. The shafts are forged to size from small billets. The ends of the axle where it enters the differential, as well as where it drives the wheel, are hexagonal. The diameter at the wheel bearing-seat is $3^3/_4$ in. and the distance across the flats of the hexagonal end at the differential is 2 7/16 in. The method of attachment to the wheel can be seen from the assembly drawing in the upper portion. The wheel is seated by collets *k*, which are jambed by tightening the axle nut, and this in turn is locked by the hub-cap. The hub-cap is attached to the rear hub-flange by three ½-in. studs and lock-washers. The two brakes are placed side by side in the drum, the same as in the Class B axle. In the Sheldon axles the cam type of brake is used on the smaller sizes, while on the larger sizes the wrap-up type is employed.

Fig. 12 shows the semi-floating worm-drive rear-axle of the Wisconsin Parts Co. The worm and wormgear complete are mounted on the differential carrier and inserted into the housing from above and attached thereto. The worm-shaft is mounted on ball bearings, the forward one being free to float; the outer race is therefore not confined endwise. The wheel is mounted on double-row ball bearings or on straight roller-bearings. The wormgear is held between the differential flanges and is piloted, thus being supported throughout its circumference. To prevent egress of oil

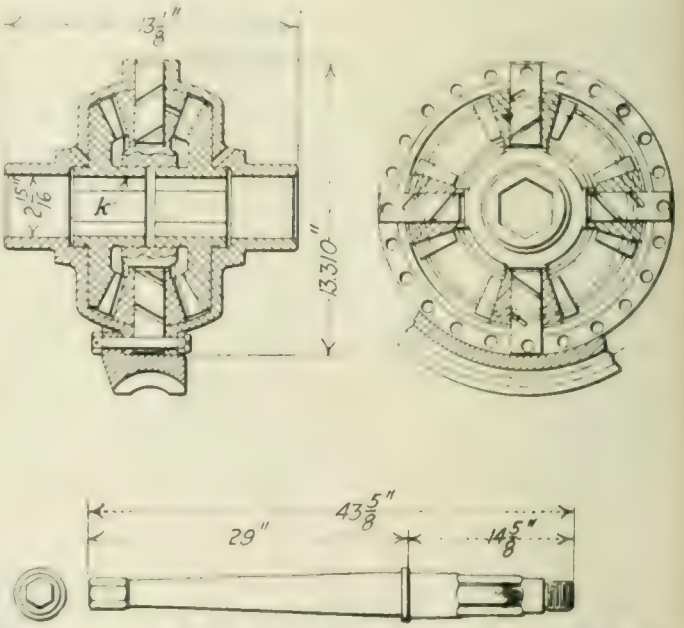
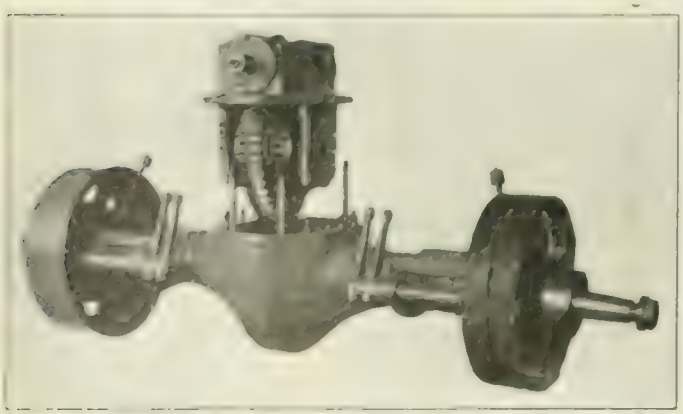


FIG. 11 DETAIL OF THE AXLE SHAFT IN THE LOWER PORTION AND PART OF THE ASSEMBLY DRAWING SHOWING THE METHOD OF ATTACHING THE WHEEL TO THE AXLE



through the wheel bearing onto the brakes, two felt washers *t* are provided, one just behind the wheel bearing and one in the adjusting nut. The brakes, as may be noted, are both internal and mounted on a *double* brake drum. The drums are placed concentrically, thereby permitting the use of comparatively narrow brake-drums which enables the wheels to be located closer to the spring-seats. The housing is a malleable casting. The drive-shafts are made of No. 3140 S.A.E. chrome-nickel steel, heat-treated to show an ultimate strength of about 200,000 lb. per sq. in.

Fig. 13 shows the axle constructed by the Timken Detroit Axle Co. for trucks of from 2 to 5-ton capacity. In these models this company uses the full-floating axle, while in its smaller models, having capacities of from ¾ to 1½ tons, it uses the semi-floating type. All the Timken axles are worm-driven, and the entire construc-

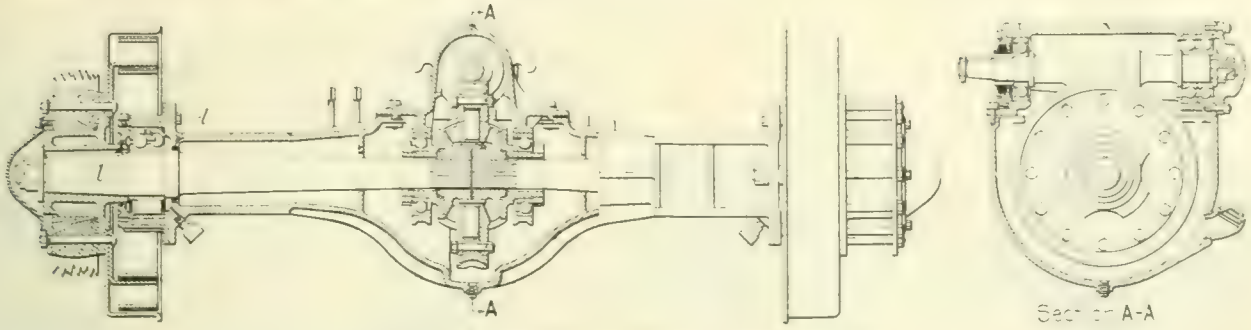


FIG. 12—A SEMI-FLOATING WORM-DRIVE REAR-AXLE

tion is similar to the Class B axle, the chief difference being in the brakes.

Fig. 14 is a side view of the brakeshoes in the brake-drum. There are four shoes, *m*, *n*, *o* and *p*, each extending about one-fourth of the circumference of the drum, but covering full width, as seen from the assembly at *q*. The brake cams, *r* and *s*, which are operated by the brake-shaft levers *t* and *u* respectively, actuate two opposite shoes; *s* actuating *m* and *n*, and *r* operating *o* and *p*.

Fig. 15 is the fixed-hub or semi-floating type of Timken rear-axle. This differs from the type illustrated in Fig. 13 in that the axle shaft is fixedly attached to the wheel direct, instead of by a splined driving-plate, and the axle supports the load of the wheels. In full-floating axles there is a greater stress on the axle housing, near the wheel, than in the fixed-hub type.

The Pierce-Arrow 3½ and 5-ton truck axles are full-floating; the wheels are provided with taper roller-bearings, while the worm and wormwheel are supported on ball bearings. A propeller-shaft brake is used as the service brake, while the emergency brake acts on the inside of the brake-drums, as seen in Fig. 16, which is a cross-section of the rear-axle assembly. In its 2-ton model this firm employs taper roller-bearings throughout and also for the worm. The axle is semi-floating; the two brakes are placed side-by-side in the rear-wheel brake-drums. Instead of driving through torque and radius-rods, the Hotchkiss drive is employed in the small models.

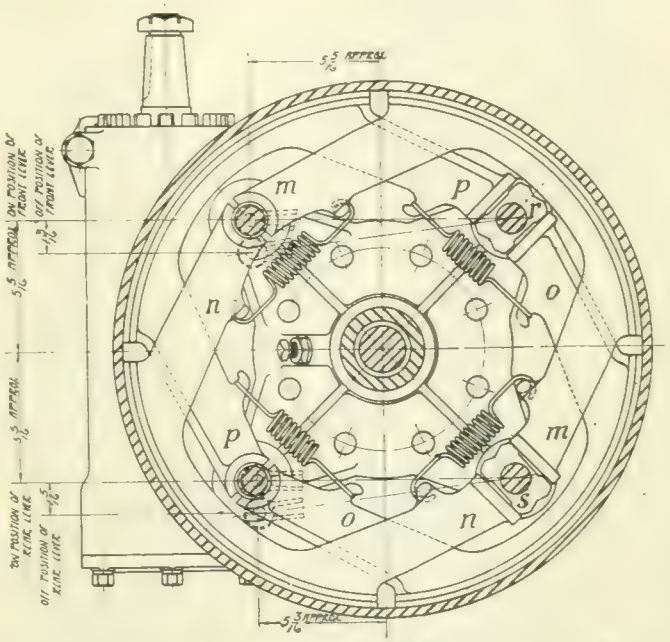


FIG. 14—A SIDE VIEW OF THE BRAKE-DRUM USED WITH AXLE SHOWN IN FIG. 13 ILLUSTRATING THE ARRANGEMENT OF THE BRAKE-SHOES

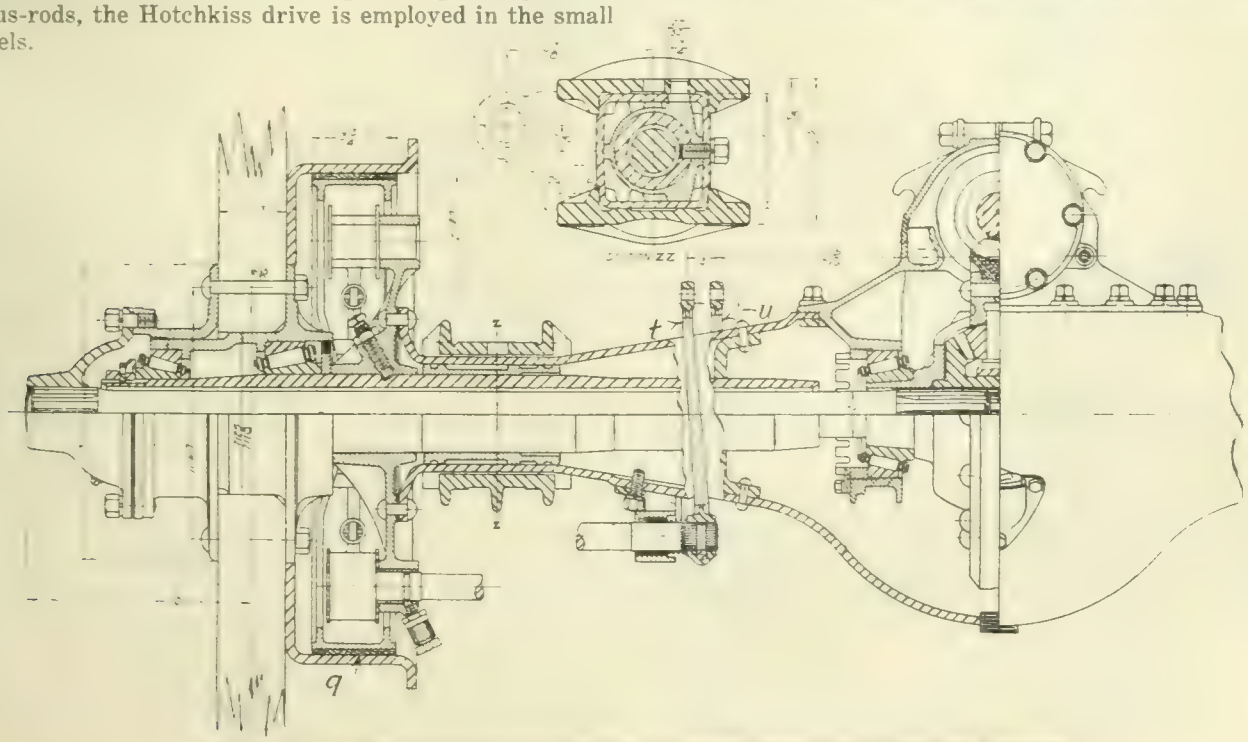


FIG. 13—A FULL-FLOATING AXLE FOR TRUCKS RANGING FROM 2 TO 5 TONS IN CAPACITY

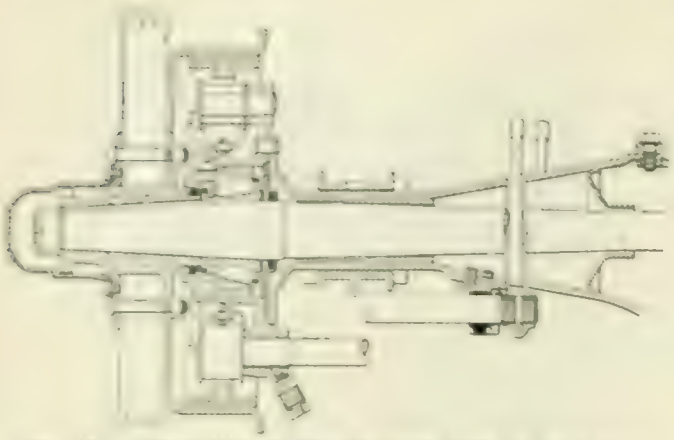


FIG. 15—A FINAL DRIVE OF SEMI-FLOATING TYPE OF REAR AXLE

Fig. 17 shows the worm mounting of its larger models. The radial load is carried by single-row ball bearings, one in the front and one in the rear, while the thrust in both directions is taken by a double-row ball thrust-bearing located at the back. The differential bearings consist likewise of single-row balls for supporting the radial load, as seen from Fig. 16.

EXAMPLES OF INTERNAL-GEAR DRIVES

Fig. 18 is an assembly drawing of the ¾-ton Torbensen axle. In this axle the load-carrying member is of I-beam section. Such a section can be made lighter for a given strength and a given direction of the vertical stresses than round or square sections. The objection cited against I-beam rear-axles is that the stresses are imparted to it from other directions than purely vertical.

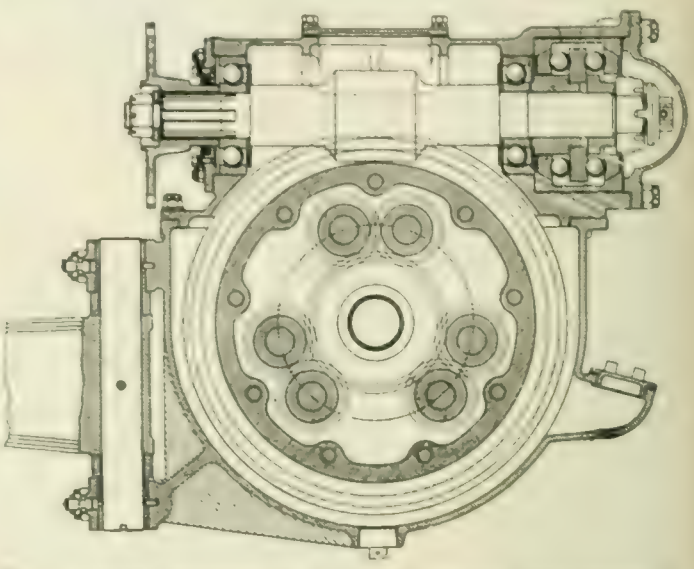


FIG. 17—WORM MOUNTING OF A LARGER TYPE OF AXLE SHOWN IN FIG. 16

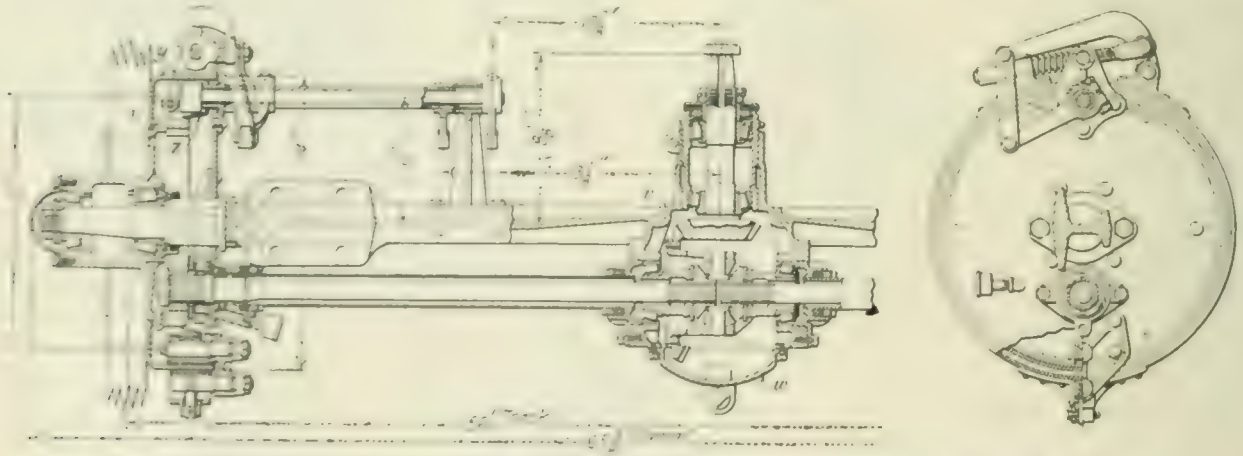


FIG. 18—ASSEMBLY DRAWING OF A ¾-TON AXLE HAVING THE LOAD-CARRYING MEMBER OF I-BEAM SECTION

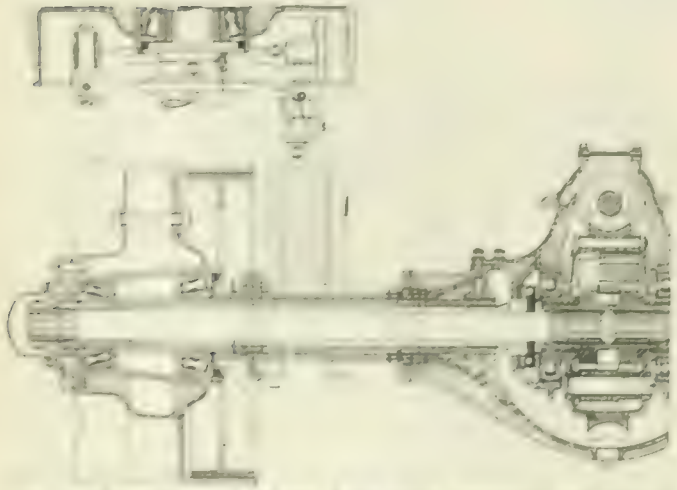


FIG. 19—DETAILS OF THE REAR AXLE ASSEMBLY FOR TRUCKS RANGING FROM 2½ TO 3 TONS IN CAPACITY

When striking an obstruction on the road, or when applying the brakes and locking the wheels, the stresses are not entirely vertical; however, by far the greatest loads in practice are substantially vertical. At the ends of the I-beam are tapered holes, 4¼ in. deep, for inserted spindles, made of No. 6130 S.A.E. chrome-vanadium steel. The advantage claimed for these spindles is that they can be made to the exact hardness desired more easily, and by employing a higher grade of heat-treated alloy steel the spindle diameter may be made smaller, which permits the use of smaller bearings.

Another special feature of the Torbensen axle is that the jackshaft is carried behind and supported in the center by the I-beam axle. At *v* can be seen how the differential housing of the jackshaft is shouldered where it is attached to the I-beam axle by cap-screws. Locating the differential housing behind the load-carrying member permits the removal of the housing cover *w* for inspection and adjustment of the gears and bearings. The advantage claimed for the feature of attaching the

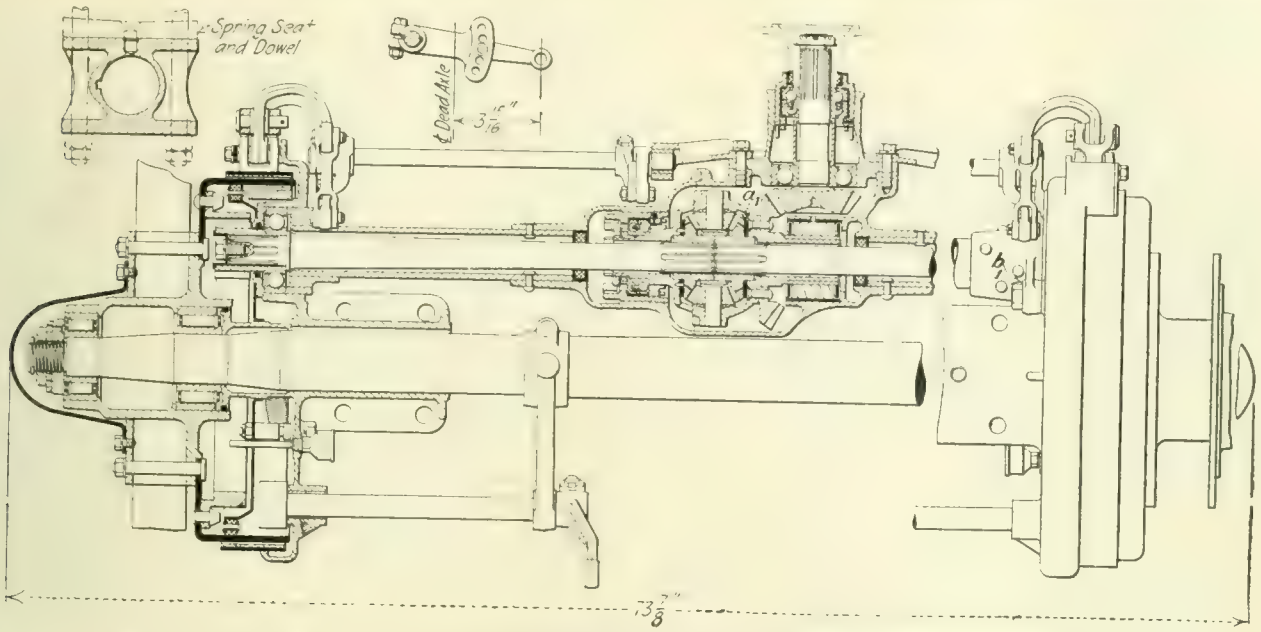


FIG. 19—AN EXAMPLE OF A ROUND INTERNAL-GEAR AXLE MADE FROM CHROME-NICKEL BAR STOCK

differential housing rigidly to the load-carrying member is that under any deflection of the axle the jackshaft will flex with it and thus maintain the line contact of the spur gears, whereas, if these members are not attached together rigidly, any strain in the load-carrying member will deflect it and, since the shaft with the pinions is not deflected, only the outer edges of the teeth will come in contact with the internal gears.

The internal gear is attached to the wheel hub by a press fit and 12 5/16-in. rivets, as shown at *x* in the assembly drawing. This is claimed to be a distinct advantage over the constructions where the ring-gear is held in place by bolts passing through the gear and the woodwheel, where the gear is seated on a wooden surface. Attaching the gear to the hub direct provides a metal-to-metal contact, which tends to keep the gears in line, while when it is attached to the wheels by bolts it is liable to distortion when drawing up the bolts in assembling. The brake-drum *y* is mounted on the wheel to admit of some space between it and the internal gear, thereby allowing sufficient room for the brakes, which may both be placed inside the drum, if the latter is widened. In the drawing one internal and one external brake are shown, and a sheet metal ring *z* is employed to keep dust and dirt from the spur gears and to shield the brakes from the lubricant of the gears. The attachment of the brake-shaft bracket to the I-beam is shown in the assembly. It is stated by the makers that this ¾-ton axle weighs about the same as a bevel-gear-drive axle suitable for a 3000-lb. passenger car, due chiefly

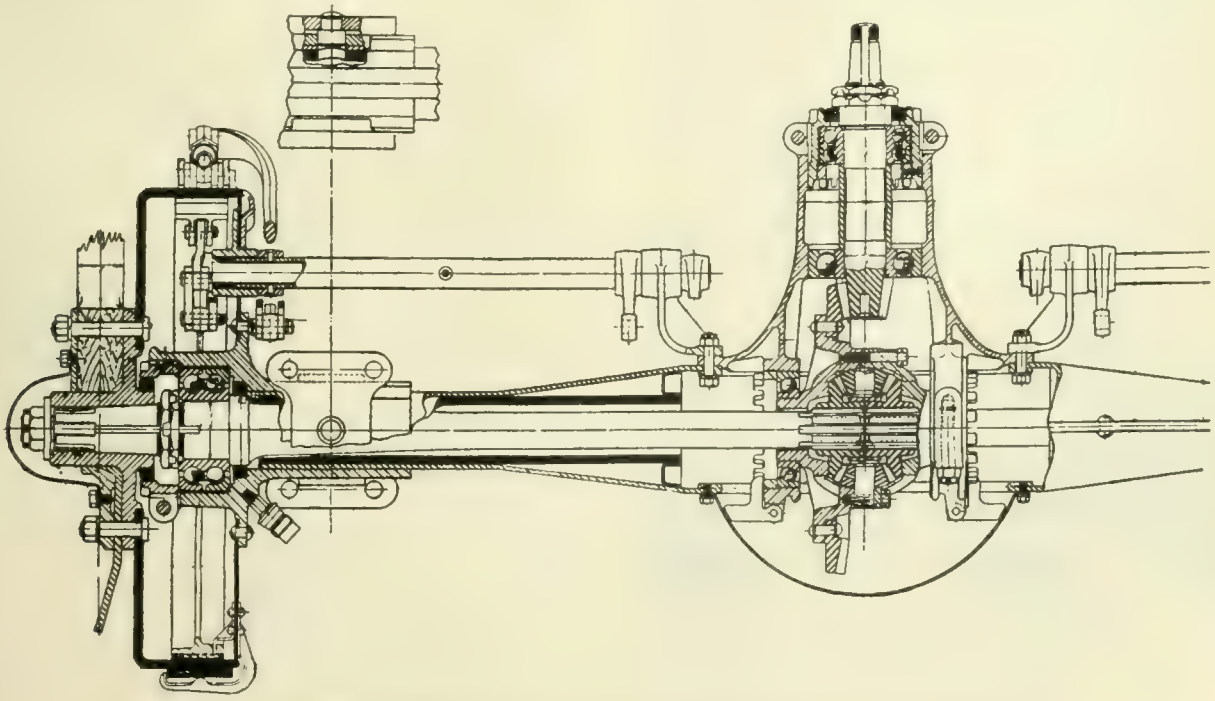
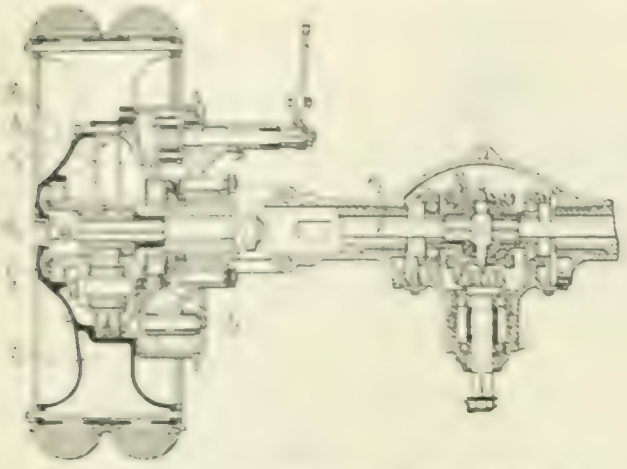


FIG. 20—A 1-TON BEVEL-DRIVE AXLE FOR TRUCKS EQUIPPED WITH PNEUMATIC TIRES



[illegible]

in the fact that the power transmitting parts are light, the live axle and the bevel gears not being subjected to the maximum torque.

In the Russell internal-gear axle, shown in Fig. 19, a round axle, made from chrome-nickel bar stock, is used. It is heat-treated at the mill, which is claimed to give uniform physical properties throughout. The load-carrying member is behind the jackshaft, which permits the use of a shorter propeller-shaft. Furthermore, by having the jackshaft pinion in front of the wheel center the pressure of the driving pinions on the internal gear is downward, and this reduces the load on the wheel bearings considerably. If the pinions are behind the dead axle, the bearing pressures arising from the drive are added to those due to the static load on the wheel.

The jackshaft housing is entirely independent of the load-carrying axle, and it is not rigidly bolted to it. With all load carriers there is some deflection due to the strain in the metal, especially under severe service, and it is claimed that by not having the jackshaft rigidly attached to the axle no part of the strain of the load-carrying axle is transmitted to the jackshaft. The jackshaft housing is rigidly attached at one end to the brake support and loosely on the other end. A certain flexibility is thereby obtained, when the load-carrying member is deflected under load or when the traction on one wheel should be greater than on the other, which, it is said, tends to prevent misalignment between the spur-gear pinion and the internal gear. This axle has a normal capacity of about 2 tons. The maximum load on both spring-pads is 4100 lb., which includes the portion of the weight of the [illegible] resting on the spring pads. There is an [illegible] between the inner races of the wheel bear-

[illegible]

ings, but the construction embodies the adjustment adopted by the Society for front-wheel bearings that eliminates this spacer.

A pressed-steel cover having a felt packing on its periphery is mounted within the brake-drum, to exclude dirt from the internal gear and to prevent the gear lubricant from reaching the brake-band. It is attached to the brake support a by bolts as shown, and is centered upon the wheel spacer. A felt ring is provided for the jackshaft outer bearing. The jackshaft pinion can be removed without disturbing the jackshaft. The jackshaft torque-yoke shown at the right is keyed to the jackshaft housing and attached to the brake support at b, thus carrying the entire torque reaction, for the jackshaft housing is not rigidly attached at the left side.

Fig. 20 is an illustration of the Russell 1-ton bevel-drive axle for trucks equipped with pneumatic tires. Ball bearings are used throughout, New Departure double-row bearings being provided in the wheels and at the front end of the drive-pinion shaft to take the thrust in both directions. The axle is built for a truck-speed of from 25 to 35 m.p.h. The ratio in the rear axle is 6.33 to 1, and to give sufficient road clearance the pinion has only six teeth.

Fig. 21 shows the construction of the 3½ and 5-ton internal-gear drive axles of the White trucks illustrated in Fig. 22. In these axles the White Company uses one internal brake at the rear wheels, serving as the emergency brake, and a foot-operated propeller-shaft service brake. The first reduction is obtained by spiral bevel-gears in the center of the axle and the second by the pinion c_1, Fig. 21, which is supported by two ball bearings d_1 and splined to the axle or drive-shaft e_1; this pinion meshes with an idler or intermediate gear f_1, running on Hyatt roller bearings, which in turn meshes with the wheel ring-gear g_1, which is plainly visible at the right of Fig. 22. The joint between the wheel and axle housing is near the housing center at h_1, Fig. 21; hence the gears can run in a bath of oil with less danger of leakage than if there were a joint at, or near, the periphery of the drum. The wheels are full-floating, each wheel being supported by two ball bearings, i_1 and j_1, placed a great distance apart to reduce the bearing pressures.

In the internal-gear-drive axle used on the 1-ton truck built by the International Harvester Co., shown in Fig. 23, the load-carrying member k_1 is a chrome-nickel steel forging having a round section like the Russell, except that in the center it is flattened out and curved to make room for the differential housing. The latter is piloted to the differential carrier as shown. The driving-shafts l_1 are exposed between the differential housing and the brake-support castings which contain the spur-gear pinion. The internal gear is enclosed by this brake-support casting to which are fitted the two internal expanding brakes. All the bearings are of the Hyatt roller type with the exception of a double-row bearing for the internal spur-gear pinion. The lateral thrust against the wheel in either direction is taken by the two sets of thrust-washers, one of bronze placed between two steel washers. All the Hyatt bearings in these axles are of the same size, which is an advantage when repairs are necessary. The clearances and the drive fits of the various parts are noted.

Fig. 24 gives a general view of the 1 to 1½-ton Walker-Weiss truck axle built by the Flint Motor Axle Co. The first reduction is obtained in the center of the axle by a pair of bevel gears; the other reduction takes place at the outside of each wheel through a stationary ring gear and three pinions attached to the wheel driving-cap. This

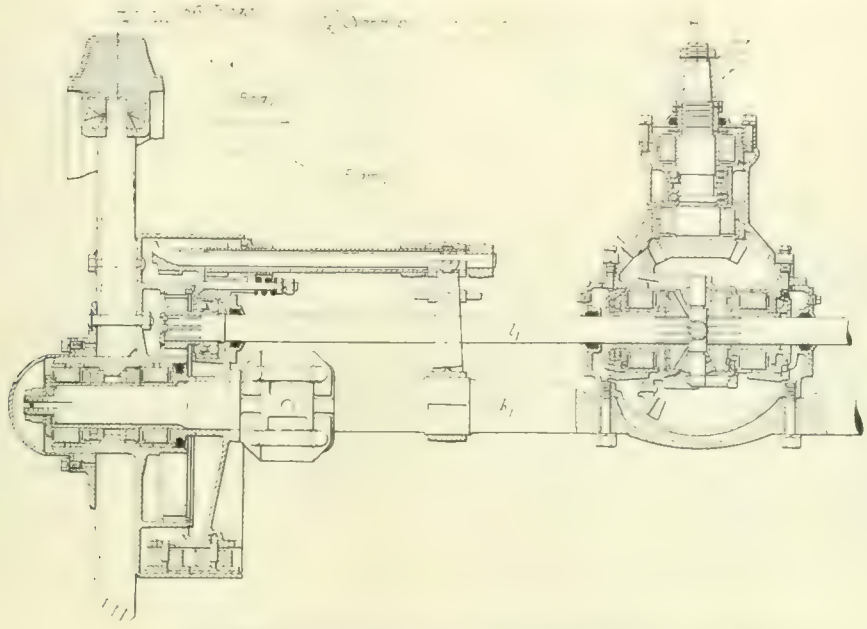


FIG. 23—INTERNAL-GEAR-DRIVE AXLE USED ON A 1-TON TRUCK

is said to reduce the size of the gears required. By having a plurality of pinions the tooth pressure is small as compared with the single pinion drive; hence smaller gears may be employed. The main shaft, made of chrome-nickel steel, has attached to its outer end a gear pinion which meshes with three planetary or idler gears that are in mesh with the stationary ring-gear. When the shaft rotates the pinion m_1 at its outer end drives the idler gears n_1. The ring-gear v_1, being stationary, takes the reaction from the idler gears. In this manner these idler gears, which are studded to the wheel driving-flange p_1, rotate about the studs and, since the ring-gear is stationary, the driving-flange will be rotated in a forward direction, the same as the drive-shaft. The housing, which covers the driving-shaft, serves as the load-carrying member. The wheel bearings, the driving pinions and idler pinions run in a bath of oil. As in full-floating axles in general, the gears can be replaced without jacking-up the truck or removing the wheels. It is claimed that in this construc-

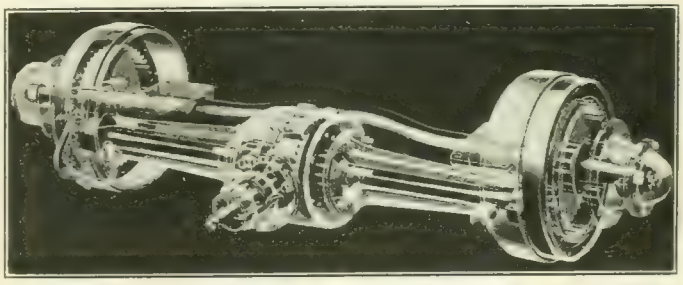


FIG. 25—AN AXLE WITH A ROUND LOAD-CARRYING MEMBER THAT IS BENT IN THE CENTER TO CLEAR THE DIFFERENTIAL HOUSING

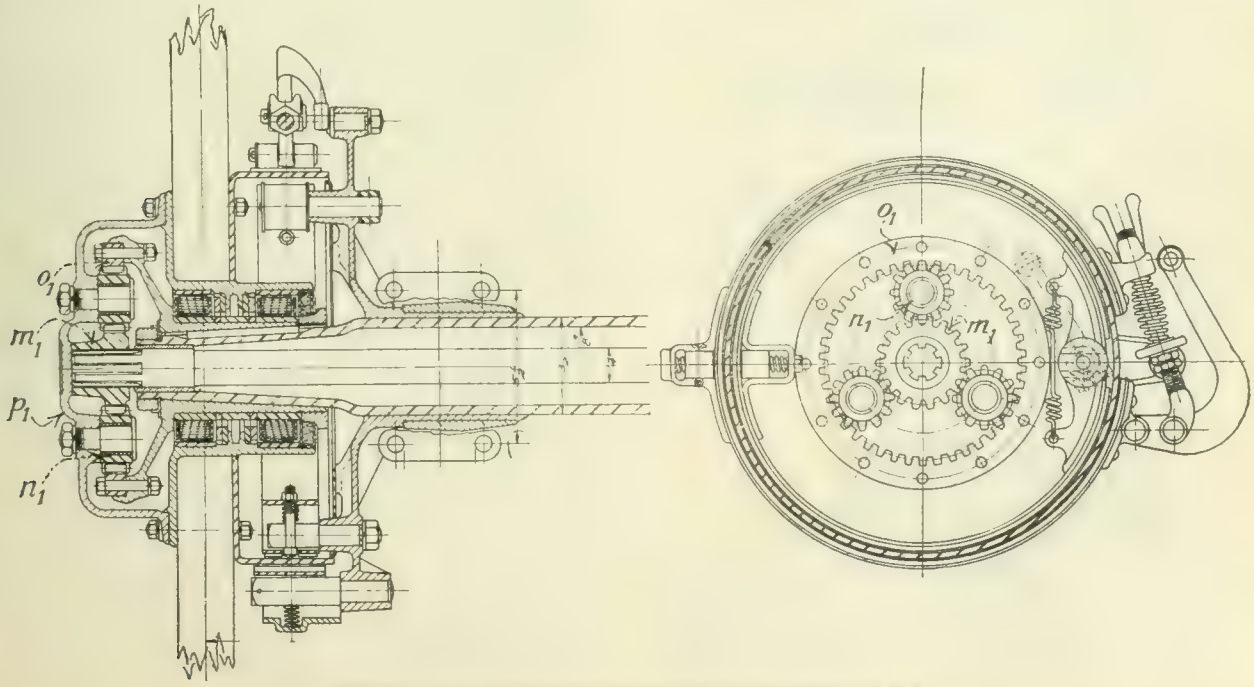


FIG. 24—A 1 TO 1½-TON DOUBLE-REDUCTION TRUCK AXLE

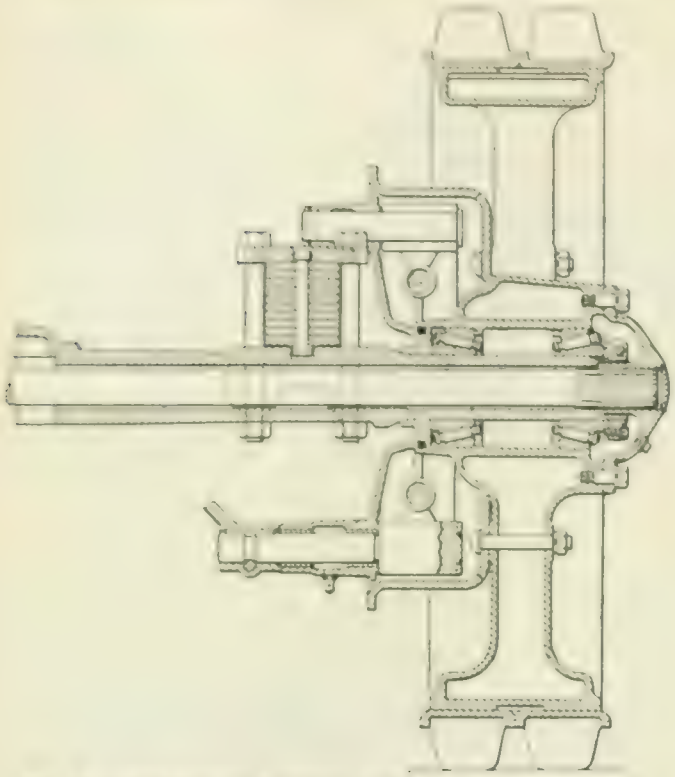


FIG. 26 CROSS-SECTION THROUGH THE REAR WHEEL OF DOUBLE-REDUCTION AXLE

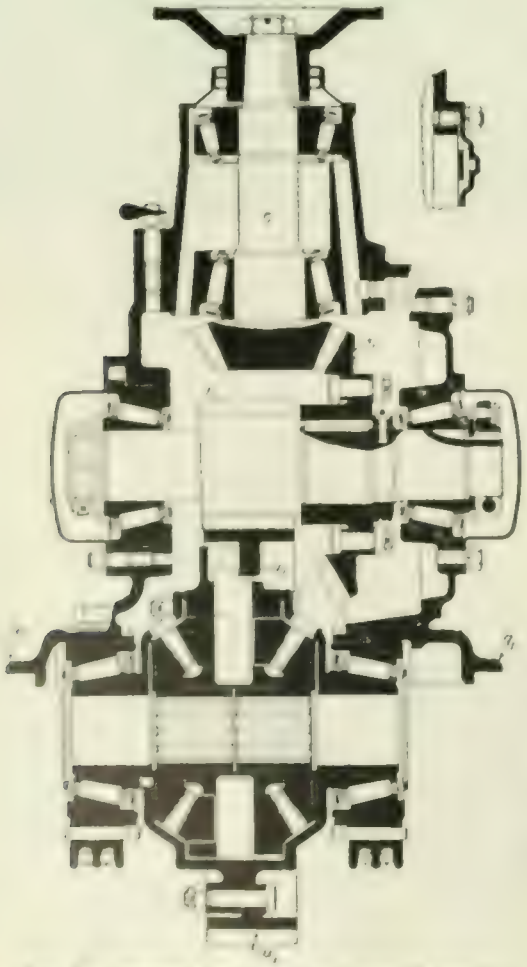


FIG. 27 SECTION THROUGH THE DOUBLE REDUCTION OF THE SAME AXLE AS ILLUSTRATED IN FIG. 26

tion the internal gears are protected absolutely from dust and grit and that the oil flows from one wheel to the other through the axle housing and the differential.

The Clark axle, Fig. 25, employs a round load-carrying member, bent in the center to clear the differential housing. In this axle the drive-shaft is in front of the load-carrying member; the advantages of such a construction have been cited before. The brake-drum contains a partition to separate it from the internal gears. Hyatt roller-bearings are employed to carry most of the radial load, while the double-row ball-bearings at the outer ends of the axle and at the pinion shaft are used to carry a portion of the radial load and to take the thrust in both directions, and thrust ball-bearings are installed behind the differential housing. The internal gear is attached to the hub by bolts passing through the gear, the brake-drum and the wheel spokes.

THE DOUBLE-REDUCTION AXLE

The term double-reduction axle as employed today denotes a two-fold reduction in the center of the rear-axle

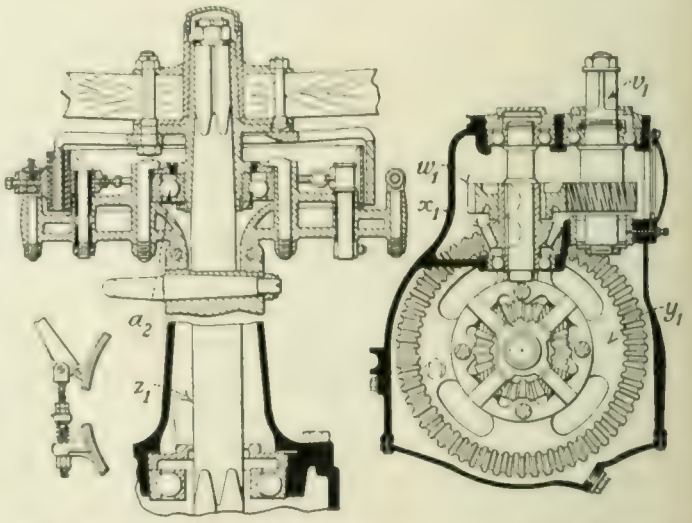


FIG. 28 ASSEMBLY OF A 1½ TO 2-TON DOUBLE-REDUCTION TRUCK AXLE

housing. In some of the double-reduction axles the first reduction is accomplished by spur gears or spiral spur gears, as in the White 1½ to 2-ton axle, and the second reduction by bevel gears; while in others, like the Autocar and the small Mack truck, the first reduction is by bevel gears and the second by spur gears. The International Motor Co., which used a worm, as well as a chain, drive on its 1½ to 2-ton model for several years, has recently abandoned the worm drive altogether and substituted a double-reduction axle.

The main axle-chamber is a drop-forged banjo or yoke, with hollow tubular ends carrying the axle shafts, as in the conventional live axle, with the driving members enclosed within the banjo yoke. The drive from the propeller-shaft is in a straight line, passing first through a pair of bevel and then through a pair of spur gears to the differential. The banjo is inclined at an angle of 45 deg., to be in a better position to resist road shocks, when hitting obstructions on the road, which are normally oblique in direction.

Fig. 26 shows a cross-section through the rear wheel, while Fig. 27 shows a section through the double reduction, including the differential; the flange q_1 being a part of the housing containing the bevel and spur gears. The pinion is made integral with the rear-axle

pinion shaft r_1; the latter drives the bevel gear keyed to jackshaft s_1, which is integral with spur gear t_1. This spur gear meshes with the big spur or bull gear u_1. All bearings in this axle are of the Timken taper-roller type; the brake-shafts have self-lubricating bushings. The advantages claimed for the double-reduction axle are that its efficiency is constant throughout

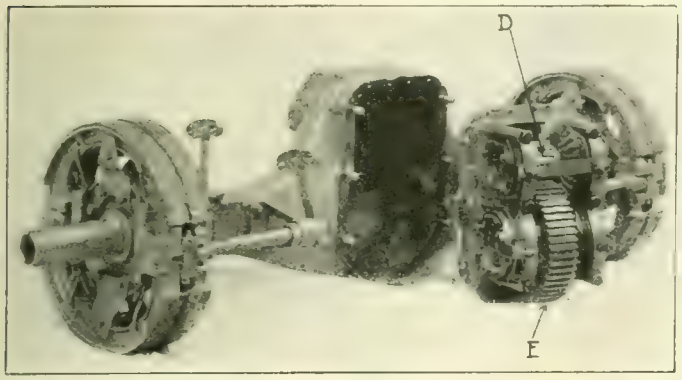


FIG. 29—A DOUBLE-REDUCTION REAR-AXLE IN WHICH THE FIRST REDUCTION IS BY BEVEL GEARS AND THE SECOND BY SPUR GEARS

speed and load ranges and wear and that it is more durable than the worm and the internal-gear drives and, like the worm drive, free from dust.

Another example of a double-reduction model is the White 1½ to 2-ton truck axle, an assembly of which is shown in Fig. 28. The first reduction is obtained by spiral spur-gears, the drive coming through the pinion countershaft v_1, with which the spur gear is made integral, the latter meshing with spiral spur gear w_1. This gear is keyed to the hub of the bevel pinion x_1, which meshes with the bevel driving gear y_1. The axle or drive shaft z_1 is semi-floating, the wheel being supported by ball bearing a_2.

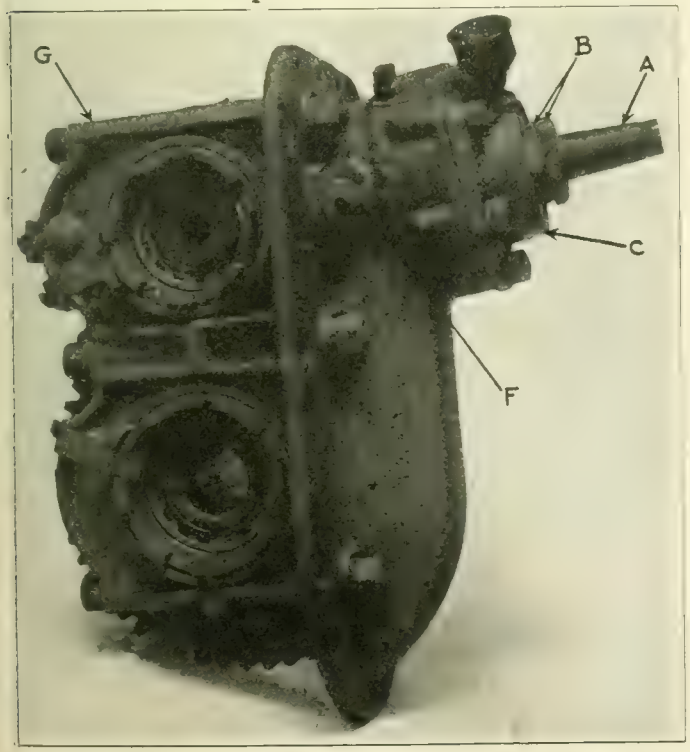


FIG. 30—A DOUBLE-REDUCTION REAR-AXLE IN WHICH ALL THE GEARS ARE ASSEMBLED ON THE FRONT COVER

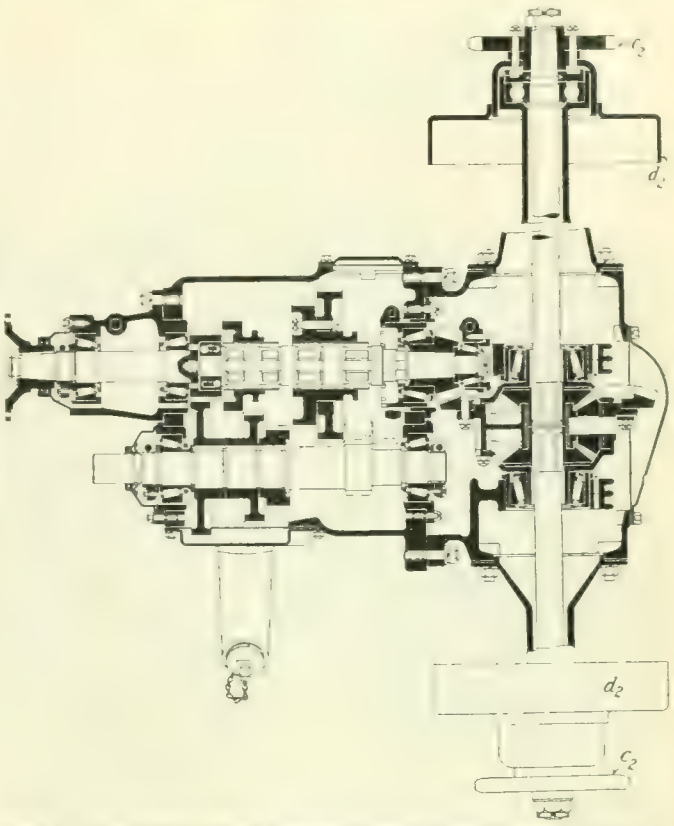


FIG. 31—SECTIONAL VIEW THROUGH THE TRANSMISSION AND JACK SHAFT OF A CHAIN-DRIVEN TRUCK

Figs. 29 and 30 show the double-reduction rear axle used on the Autocar truck. In this axle the first reduction is by bevel gears, and the second reduction by spur gears. All the gears are assembled on the front cover, shown in Fig. 30, while, for inspection and adjustment, a cover-plate can be removed from the back of the axle housing.

The pinion shaft *A* is mounted on two taper roller-bearings, which can be adjusted by the two nuts *B*. The pinion shaft and bearings are all mounted in a separate case *C* attached to the front cover. The front end of the pinion shaft is splined. A bevel pinion is pressed on this

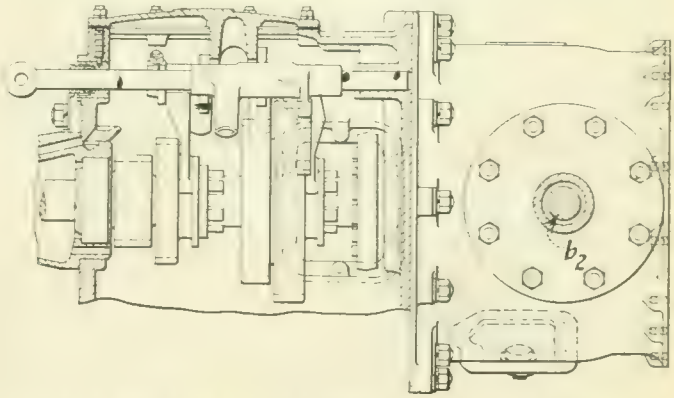
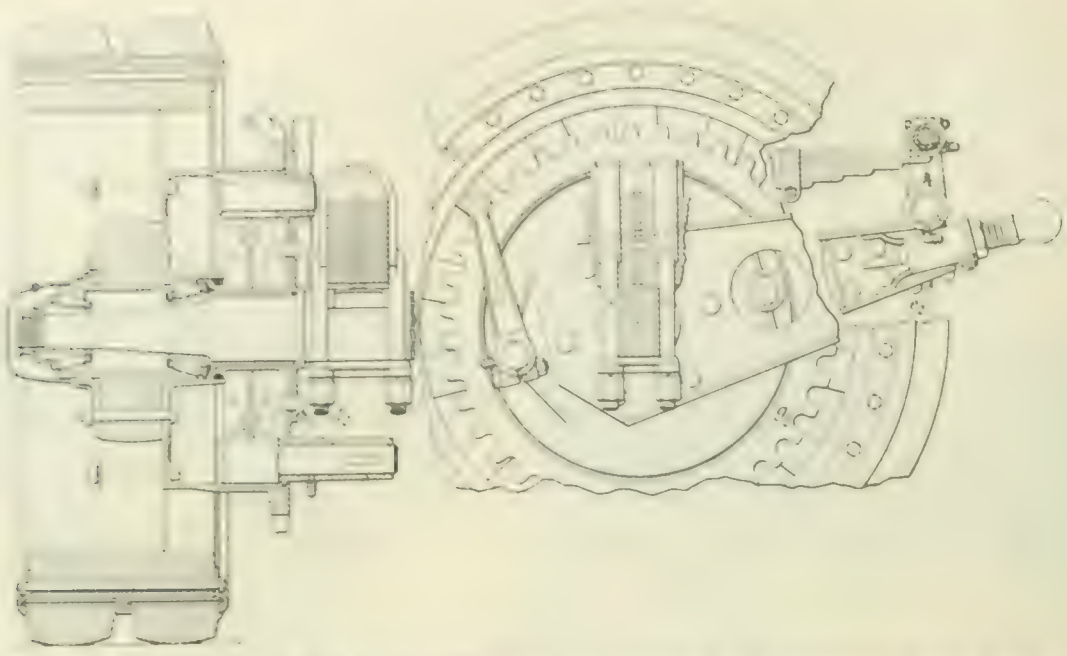


FIG. 32—A SIDE VIEW OF THE ASSEMBLY OF THE CHAIN-DRIVEN AXLE ILLUSTRATED IN FIG. 31

and is held in place by a nut and washer. This bevel pinion meshes with the bevel gear on the jackshaft which forms a unit with the small spur gear *D*, Fig. 29, which in turn meshes with the differential spur ring-gear *E*.

By removing plug *F*, Fig. 30, the adjustment of the bevel gears, when the cover assembly is in the axle hous-



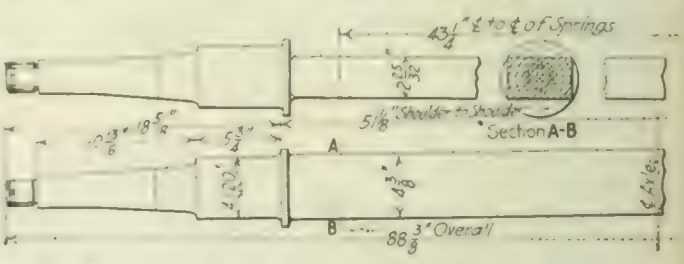
Cross Section and Side Elevation Showing the Location of the Emergency Brakes in the Rear Wheels

ing, can be examined. The spur gears are located on fixed centers of the casting, into which adjustable bearings are mounted. The whole front cover, with the exception of the bridge *G* on the pinion shaft case *C*, is a single casting; this bridge is used as a clamp to hold the bearing adjusters and retainers in position. By employing spur gears between the jackshaft and the differential ring-gear there is no side-thrust against the ring-gear. The axle is of the full-floating type. The wheel is mounted upon the tube that carries the wheel bearings. This tube is pressed into the axle housing under heavy pressure and then held in place by set-screws. In the event of any accident, this tube will sustain the damage rather than the axle housing and can be replaced at comparatively low cost. In the heavy-duty trucks the axle housings are of square section, and the tubes are pressed all the way through the casing into a web, close to the differential gears, thus reinforcing the casing.

Examples of Chain Final Drives

Fig. 31 is a sectional view through the transmission and jackshaft of the Mack chain-driven truck. This type of drive is used by the International Motor Co. on all of its heavier models. As may be noted from the drawing, the transmission case is bolted to the jackshaft case as is shown more clearly in Fig. 32, which is a side view of the assembly, a part being a section through the jackshaft. The live axle shafts are made of nickel-alloy steel and are 1¾ in. in diameter.

The entire transmission and the differential in the jackshaft housing are supported on Timken roller-bearings. With the exception of the self-aligning S.K.F. pilot bearing in the pinion gear and the ball bearings at the outer ends of the shafts. The service brake-drum hubs are keyed to the outer tapered ends of the shafts and the driving sprockets c_2, Fig. 31, are bolted to these hubs. The service brakes on the drum d_2 are of the external contracting type, 5 in. in diameter and 3 in. wide. The



Detail of the Rectangular Rear-Axle of a 5-Ton Chain-Driven Truck

emergency brakes are located in the rear wheels (see Fig. 33) and are 20 in. in diameter and 3½ in. wide.

The wheels are of the full-floating type and the drive is through a radius-rod e_2 which also performs the functions of a torque and thrust-rod. The rear end of the rod is fastened to the brake supports by rivets f_2. This rod is provided with a ball-and-socket joint at its front end. The large sprockets g_2 are integral with the brake-drum of the rear wheels. In chain-driven axles the rear axle is simply a load-carrying member or dead axle. A detail of this axle as used on the 5-ton model is given in Fig. 34, showing this axle to be of rectangular section, 4⅜ in. deep and 2¾ in. wide.

WINTER TESTS SHOW LOWER MILEAGE WITH HEAVY FUELS

In the paper with the above title that was presented at the recent [illegible] Annual Meeting by Dr. H. C. Dickinson and Lieut. R. C. Warner and that was printed in the July issue of this JOURNAL a typographical error was made in giving the increase in the average fuel-consumption in the fourth line of the second column on p. 91. As printed the statement was made that "*Under winter conditions* there is a small but definite increase in average fuel-consumption of about 30 per cent." This figure should be 3 per cent, as would be perfectly obvious from the context.

SOCIETY MEETINGS

CLEVELAND SECTION VISITS CANTON

Members Inspect Roller Bearing Factory and Enjoy Afternoon of Sports

It was a heyday in Canton on July 13. Despite the age-worn prejudice set up against Friday the 13th by those addicted to superstition, some 65 members of the Cleveland Section of the Society gathered in the village made famous by tapered rollers to disport themselves as the guests of H. H. Timken and his diminutive supporters, Porter and Buckwalter. John Younger writes that "only a schoolgirl with a rich choice and selection of adjectives could do justice to the party," and we have no reason to question the veracity of Cleveland's energetic chairman.

The morning was spent in making a very thorough inspection of the Timken Roller Bearing Co.'s plant, the party being escorted by guides who had been schooled to explain manufacturing operations to the minutest detail. The Timken factory is unique in that it houses under one roof all of the operations necessary to the production of anti-friction bearings from nature's basic materials. The members were enabled to see the production of molten steel, the pouring of the ingots, and the rolling of the blooms. The manufacture of tubing, bar-stock and wire proved to be intensely interesting. Every step in the fabrication of finished bearings was explained to the visitors. The inspection was concluded with a visit to the departments where the hardening, the grinding and the final assembly were carried on. All agreed that the Timken factory represented the last word in efficiency and presented a highly interesting show place because of the great diversity and comprehensiveness of the operations carried on within its walls.

Following the inspection, the members partook of a Timken lunch and adjourned to the shores of Canton's famous Congress Lake. Here the party split into three sections; the followers of Gene Sarazen's pet diversion hied themselves to number one tee; students of Izaak Walton rippled the placid waters with hook and sinker, and the wakeful ones of the remaining assembly disported themselves in heated contests of brain and brawn. Prizes were given to the winners of the numerous events, and the struggle for these embittered the combatants to a state of teeth-gnashing. The tug-of-war setting was devised by some engineer with a creative mind and a respect for action. The rope was stretched across a narrow creek whose banks were of about the same consistency as 600 W. The opposing teams battled to see which one would have the privilege of negotiating the ford, truly an enticing reward. The canoe-tilting event reflected exceptionally intimate knowledge of modern naval tactics on the part of the participants. Dr. Georg Madelung, bird of the air, proved to be accomplished in submarine conduct also; the Armstrong brothers, in deference to their name, proved the value of teamwork in the tilting event.

The prize fish of the day was captured by W. H. Lolley after a hard tussle. Proud of its single ounce of weight, this diminutive representative of Canton's finnish populace met its master and succumbed. Stuart Cowan sank the winning putt on the eighteenth green and Ernest Wooler sported the healthiest drive in the golf events. B. H. Blair drew the violet ribbon for his all-round efficiency in the athletic contests. His victory in the shot-put was made possible by the barring of "Tiny" Buckwalter because of the latter's affiliation with the Timken clan, which was acting as host of the day.

Tuning Up for the Boat Races on Congress Lake

The completion of the sports events found the majority of the contestants completely deenergized and possessed of the proverbial appetite of the small boy. Though less active in body, the spectators likewise had become exhausted from the violent exertions demanded by boisterous mirth during the afternoon's carnival. The three units of the party were reassembled at eventide and appeased their respective hungers at the Timken board. The gathering was addressed briefly by H. H. Timken, who had proved to be himself an able host. He related how years ago he had journeyed to New York City to hire an engineer and had returned with Herbert W. Alden, president of the Society, to whom he was forced to pay more than he, Timken himself, was getting. The prizes were awarded to the victors of the day, songs were sung and a weary but happy group of engineers returned to their respective havens.

The Cleveland Section is carrying its active program of meetings through the summer season, specializing in instructive inspection trips through representative automotive manufacturing plants. The next visit will be made to the factory of the Firestone Tire & Rubber Co. in Akron during the month of August. Full particulars of the meeting arrangements can be secured from L. L. Williams, secretary of the Section, who may be addressed at 1051 Lakeview Road, Cleveland.

Tendencies in High-Speed Marine-Engine Design

By J. G. Vincent

Motorboat Meeting Paper

FOLLOWING the presentation of this paper by L. M. Woolson a general discussion was had by those present. In every case an effort has been made to have the speakers go over their remarks before publication in accordance with the customary practice of the Society. For the convenience of the members a brief abstract of the paper precedes the discussion with a reference to the issue of THE JOURNAL in which the paper appeared so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort.

ABSTRACT

IN this paper there are discussed the general requirements of a comparatively new type of marine engine, that is, the high-speed type. The need for light weight is discussed and it is pointed out that aircraft-engine design has established a good precedent to follow, particularly with reference to crankshaft, connecting-rod, piston, cylinder and valve design.

Detailed discussion then follows concerning the requirements of this type of engine in respect to cooling, lubrication, starting, idling and general operation. The equipment to be furnished with the engine is covered in a general way and the installation requirements are touched upon.—[Printed in the March issue of THE JOURNAL.]

THE DISCUSSION

LEONARD OCHTMAN, JR.:—In any consideration of aircraft engines as applied to marine practice, we should take into account the fact that there are three supreme requirements for an aircraft engine; light weight, high power and minimum fuel-consumption. Those are desirable characteristics for a marine engine, but they cannot always be obtained because light-weight construction usually is at the expense of great reliability; also, it is very expensive on account of the extra machine work that must be done.

L. M. WOOLSON:—Reliability is a very pertinent factor that should have been covered. When first designed, the Liberty engine was required to go through a 50-hr. test which was considered extremely severe; very few aircraft engines would go through a 50-hr. test at that time. We have progressed and the Navy is to be commended for its stand in taking-on all its aircraft engines only after a 300-hr. test. I believe the present automobile-engine test is 100 hr. Hence the aircraft engine is as reliable as the automobile engine. We tested an engine for the Navy and at the end of 300 hr. that engine was practically as good as new. It developed something like 250 h.p. during that test. It was dismantled and reassembled and the only work done was in regrinding the valves. How many strictly marine engines would go through that test without trouble, and how many would do anything like as well as this so-called light-weight aircraft-engine?

I take issue with the thought that, in a marine engine, the lack of weight means a lack of reliability. In some late Navy work, it has been shown that there is no connection between light weight and reliability. We are now laying down an engine some 200 lb. lighter than the Liberty engine, but it develops more power, is far more compact and has far lower stresses in all the main parts such as the connecting-rods, the bearings and all the parts that count. It is just a matter of studying where the weight should be put. The cylinder on this engine is of 5 1/8-in. bore; the weight of the cylinder is 9 lb. The only way we are able to get these high mean-effective pressures is by keeping the exhaust-valves very well cooled. I think everybody admits that it is practically impossible to cool an exhaust-valve that is seated on a thick cast-iron wall as well as one seated on a light steel-wall. It has been recognized that we cannot get this super performance and light weight at anything like the same expense that we can build the heavier engine; on the other hand, we must also recognize that the high-speed express-cruiser, for which these engines are intended, is essentially a rich man's hobby and must always be so.

MR. OCHTMAN:—It undoubtedly is true that aircraft-engine design has gone far ahead of that of any other type of engine within the past few years, and much can be learned from it as regards engine performance, such as power output and economy, and its reliability while retaining the light weight.

CHRIS SMITH:—I am an aviation-engine man and believe that there is much difference between a good aviation engine and a good marine engine. I am satisfied that the light, properly constructed aviation-engine will outwear any marine engine we have ever made. The marine engine man has not had the money with which to experiment. A moderate sized factory could produce all the marine engines made; consequently, the income from them has been limited.

The difference between the cast-iron and the steel connecting-rod lies in the weight, and yet the light rod can stand the gaff. If I were searching for reliability, I would choose the aviation engine. The engine is one part of the proposition and the boat is the other; the model of the boat must be very accurate. We used four Liberty engines in Miss America. She showed a little weakness along the forward keel the day before the races, and two 6-ft. lengths of sheet hard brass, 4 in. wide and 3/16 in. thick, were screwed to the bottom of the boat to stiffen the keel, where the stresses were coming. They chamfered the forward end of the brass and carried it back to the step. They took the boat out and could not keep her in the water. Afterward, they let the brass extend 3/16 in. into the wood to eliminate that rough edge and it worked all right. Much depends on the construction in getting a boat to perform just right.

W. C. WARE:—Engines that run more than 1400 r.p.m. are hardly in our class. Some of the marine-engine builders seem to think they have found a necessity for oil cooling even at that speed but, after conducting many

M. S. A.E.—Vice-President in charge of engineering, Packard Motor Car Co., Detroit.

experiments we find we can do without it very nicely. We keep our oil-temperature down around 115 deg. fahr. without any difficulty. No trouble from very poor ventilation in engine compartments has been encountered. We have found a 30-deg. fahr. lower oil-temperature during the boat test than on the regular block-test which proves pretty well that good ventilation can be obtained in engine compartments. In reference to reverse gears. we are strongly of the belief that manufacturers should design reversing gears that can be flanged on to the rear end of the crankshaft. This does not mean much to manufacturers because they can put the present type of gear on without difficulty, but the man who has to take a reverse gear off "out in the woods" without proper gear pullers has a serious job on his hands.

CHAIRMAN L. C. HILL:—The matter of accessibility in marine-engine design is very important. In looking over some of the designs in the motorboat show, I find numerous cases where accessories such as starting and lighting generators cannot be removed without taking off many other parts on the boat or the engine. A few of the more progressive builders are adopting removable cylinder-heads. The average marine engine in the cock-pit of a boat is in about the most inaccessible position possible; it is certainly much easier to clean, grind valves and the like with the removable head and that should have been recognized in the motorboat field long ago. Accessibility may not be so important in boats using high-speed aviation-engines, because those people have plenty of mechanics and they usually lift the engine out of the boat to make major repairs. I have noticed boats with the oil coolers attached to the bottom of the crankcase. That necessitates the complete removal of the engine from the boat if there is ever any trouble due to any clogging up of the oil-cooling apparatus. Another example I have seen repeatedly is the installation of an engine with accessories mounted over the lag-screw holes in the crankcase flanges. That must be remedied. It is often impossible to get a lag screw of proper length into the space that is allowed between the bottom of the cylindrical generator and the hole in the crankcase flange.

H. L. BROWNBACK:—Many engines have oil gages in very inaccessible places so that, when a man fills the engine with oil, he cannot tell how much oil he has. In one case we have drilled through one of the studs going from the cylinder-heads down through the main-bearing caps to the sump and put a float and a rod with a little red ball on top so the man can see what the oil level is.

GEORGE W. WESLEY:—The reverse-gear manufacturers are absolutely confined by a cast-iron fence. They have a compartment on the rear end of the engine. If we consider making the least change or improvement, we have to go all over the basic plans of every manufacturer that we are selling and keep within that fence; sometimes there is less than ⅛-in clearance. The reverse-gear manufacturer has to make a product that can be sold commercially and to the largest number of engineers. When it gets down to making a special job for each one, it will make the expense too great. We are confined by the price and the cast-iron fence that the engine builder puts around the rear end. The reverse gear has to be manufactured to be commercially practical, but if we make any changes, those changes have to take into consideration every engine factory that we are selling. We have had discussions on changes that lasted for hours. We probably have from 75 to 100 different designs for reverse gears in our office. Some of them we consider ideal, but when we endeavor to provide each engine builder with a reverse gear that will meet his requirements, we are up against a pretty stiff proposition; so, we have to satisfy the majority of cases and not individual ones. If we make a change, that change must be such that it can go into every compartment of every engine builder we are selling.

CHAIRMAN HILL:—The motorboat industry has not appreciated that any clutch and any transmission will fit the rear end of any engine in an automobile or motor truck today because S. A. E. Standards are followed. The Society has endeavored many times to bring about such standardization in the motorboat field. It will save an immense amount of work, not only in the engine construction itself, but in the mounting of electrical starters, generators, clutches, reverse gears and other detachable units. The Society is ready to apply standardization to the motorboat field at any time the industry will join with us in establishing such standards and, moreover, will use them when once formulated.

MR. WESLEY:—Formerly, in our gear works, we built a different brake band and different after-bearing; the base would vary from 1 in. above the central line of the shaft to 1 in. below. We have been working on the elimination of different parts so that practically every brake band and after-bearing would be on the central line of the shaft; now, practically all of them were on that basis. if we can get the other standardization that we have been working on ourselves, and if the Society will influence the engine builders along the same line, much benefit for everybody will result.

MR. WARE:—The gear manufacturers are fairly close together now and very little work is needed to standardize them further so that a number of different gears could be dropped into the same case. We have looked into this very carefully in the last 2 years. The gears are fairly well standardized now for lengths and diameters; the main difficulty lies in the position of the cross-shaft bearing, that is the shaft which controls the clutches. When standardized in the manufacture of a gear-case cover that carries this cross-shaft bearing, it cannot be changed even ⅛-in. without spending a considerable sum of money on patterns and fixtures. It would seem to us that the reverse-gear manufacturers should get together with a view to keeping their new equipment interchangeable with one another.

Chairman Hill is right in saying that there should be more motorboat standardization. Our company stands ready to do anything it can along this line. It is highly desirable. We use the S. A. E. Standards in every possible way and many a design is thrown out because it is not adaptable to them.

COMMANDER S. M. KRAUS:—We have had cases where a single ship of the Navy was supplied with power boats that had engines of five different types and ignition apparatus of seven or eight different types. Where some of the engines were of the same manufacture but of different model with different ignition apparatus, it thus became necessary to carry spare parts for about three or four times as many engines as we should have. The result was that the Department has felt that it was almost impossible to buy its power-boat equipment in the open market. We do not want to build it, but we cannot keep it running if we have so many different kinds. I think that nothing would be more important to the industry than to standardize, although the standards should not be too rigid.

In reference to the relative cost of the light-weight and the medium-weight engines, sooner or later we will find that there is a field for the application of marine engines where the higher price of the light-weight engine will be

fully demonstrated [illegible] not only due to the [illegible] but also because much of that [illegible] When we really [illegible] in lieu of long-distance [illegible] I think we will find that we can very easily afford to pay the higher price that goes with the [illegible] construction. I believe that the higher prices will be reduced materially in the future. Manufacturers will [illegible] offer a smaller or a more accessible boat engine that has additional features that will sell the boat and be equipment to the owner who wants a pleasure boat or to the owner who wants a working boat, because these extra facilities will render the boat useful for a service that we otherwise do not attempt with the [illegible] small marine engine. We found that to be true in many [illegible] in naval vessels.

To-day, in cargo and passenger ships using internal-combustion engines, there is considerable reluctance to compare them with the cost of Diesel and other powerplants. Many have overlooked the chief difference and have compared the ships and their powerplants, ship for ship, but with different powerplants. I think the same situation will be found in the class of power boats and marine engines in which you are interested. Freight and passenger-steamship owners are discovering today that they must not compare a vessel of certain dimensions that is designed for one kind of power with the same size of vessel equipped with another type of power. You can build a radically different boat, get a very radically different service, apply it to radically different purposes and incur great additional expense, but with superior economy that you can build into the boat at the same time. I believe superior economy would cost nothing.

A. D. T. LIBBY:—I saw an engine at the Chicago automobile show that is, to my mind, the coming engine, not only in the marine field but in the farm-tractor field and in the automobile field itself. It answers many of the criticisms that have been directed toward the Diesel type of engine, one of which is that the Diesel engine is very heavy with respect to the amount of horsepower delivered. This new engine is of the semi-Diesel type and does away with many of the objectionable features of the Diesel engine, such as the air compressor and the air coolers, and the weight is very much less, comparatively speaking. I believe that it would be lighter than our present automobile engines for the horsepower delivered. The builder claims that this little engine will consume as little as 0.4 lb. of fuel per b.hp-hr., an enormous advantage; it is, therefore, an engine light in weight and high in fuel economy. None of the difficulties that Mr. Woolson mentioned with reference to carbureter and ignition troubles are encountered in this engine because it uses no carbureter and has no ignition system because it is of the high-compression type.

CHAIRMAN HILL:—It may straighten out a misapprehension held by some people to say that the Society's standardization work does not mean standardization to the point of telling a man what bore and stroke an engine should have, what type of water-jacket or any similar matter of design. The S. A. E. Standards relate principally to dimensions resulting in interchangeability.

J. G. VINCENT:—I believe our chairman, Mr. Hill, touched on a very important point when he compared the automobile industry with the motorboat industry in respect to interchangeability as a result of following standards. As very few of the marine engine builders manufacture their own reverse gears it would be a matter of great convenience and represent an important economic advantage if different makes of reverse gear could be applied to the same engine with no change in the reverse-gear housing and other important mounting dimensions. I would heartily indorse any such move toward standardization of this kind and would be glad to submit drawings of our own engines to representative reverse-gear manufacturers and any Society committee that may be formed to handle this subject.

DIRECT DETERMINATION OF DEW-POINTS OF GASOLINE-AIR MIXTURES

A METHOD of determining directly the dew points of gasoline mixtures in the proportions required for use in internal-combustion engines has been devised by W. A. Gruse and [illegible] presented to the division of petroleum chemistry of the American Chemical Society, in a paper read before that society at New Haven, Conn., on April 5, 1923. It is based on a method in the fundamental application of the dew-point of a gasoline-air mixture and consists of blowing a fuel mixture of known composition against an internally cooled metallic surface and observing the temperature at which dew is formed.

A detailed description was given of the apparatus used in making the determinations and the results obtained were compared with those reported by R. E. Wilson and D. P. Barnard, who, in their method of equilibrium mixtures in contact previously described by them. The distillation curves of three commercial fuels bought in the open market at Pittsburgh were plotted, their dew points were investigated and the effects of adding 1 and 2 per cent of benzene were observed with a view to determining the sensitiveness of the dew point to the presence of small amounts of heavy ends. Increases of from 4 to 6 deg. in the temperature at which dew formed were noted with practically all of these fuels.

A direct determination of the dew-point of samples of the same fuels used and offered for test by Wilson and Barnard showed that their figures are approximately 20 deg. lower than those determined directly and that the change in the dew-point corresponding to a change from a 12 to 1 to a 15 to 1 mixture is of the order of 7 or 8 deg. when measured directly, whereas Wilson and Barnard in their tests previously referred to found a uniform variation of approximately 4 or 5 deg. for a number of different fuels.

A comparison of the figures for a second group of fuels shows that the direct determination gives dew-points that are higher in all cases than those arrived at by the equilibrium mixture. The direct method is said to embody the following features: (*a*) the apparatus can be constructed in an ordinary laboratory and machine shop; (*b*) with a little practice the dew-points can be read with fair accuracy and reproducibility; (*c*) it is believed to be sufficiently direct to be free from large errors; and (*d*) it applies to volatile fuels of any nature. It is offered tentatively as suitable for the direct determination of the "effective" volatility of motor-fuels with the idea that it may be useful in studying specifications and blending operations and for the control of other methods of evaluation.

The paper will be published in full in the August issue of the *Industrial and Engineering Chemistry*.

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

MOTION AND FORCES BETWEEN WHEEL AND ROAD

THE subject of the so-called impact forces between the wheel and the road has been widely discussed of late and the results of experimental measurements have been published particularly by the Bureau of Public Roads. The subject, however, still seems to be rather an indefinite one in the minds of most engineers.

It is recognized in a general way that the tire characteristics, the speed and the ratio of the sprung to the unsprung weight are of prime importance, but just what relation they bear to the effect produced on the road by the vehicle seems not to have been very clearly analyzed. However, some phases of this problem are capable of definite mathematical expression and others can be stated approximately in mathematical terms.

One of the simplest cases of impact occurs when one or both wheels of a vehicle either drop from an obstruction or are projected into the air by going over an obstruction and then return to the road. General equations can be written which are applicable both to this and to other sorts of impact forces as well.

In considering this problem it is necessary first to clear up one point that is not always appreciated. This is the distinction between the *total energy* of an impact blow and the *maximum force* produced by it. When the blow is cushioned by a tire there is no fixed numerical relation between the two. The total energy is determined by the sprung and the unsprung weight and the spring constant for a given height of drop, while the maximum force depends upon the tire. It is the latter element alone that is of importance so far as the vehicle is concerned, and we believe of major importance also as regards the effect on the road.

The actions treated mathematically in a paper to be presented in the September issue of THE JOURNAL may be described briefly as follows: Consider the body and the axle at rest so far as vertical motions are concerned, with the springs under deflection carrying the load, as when traveling on a level road. The wheels are then allowed to drop freely for a specified distance as by running *rapidly* off an obstruction. The wheels are projected downward by gravity plus the force exerted by the springs. They therefore acquire a certain downward velocity and consequently an amount of kinetic energy equal to $\frac{1}{2}\ mv^2$ which is the total energy transmitted to the road by the wheels for this particular drop, and would be the same for pneumatic, solid or steel tires, except for a small difference readily accounted for.

The maximum force or load produced which represents the maximum load imposed on the road and on the axle itself, however, depends entirely upon the distance in which and rate at which this amount of energy is transmitted to the road; in other words, it depends upon the total depression of the tire from the instant it strikes the road to the instant of greatest depression. This total force is the sum of (*a*) the impulsive force represented by the maximum rate of deceleration of the wheels which coincides practically at least with the maximum tire depression, (*b*) the weight of the axle, and (*c*) the static force applied by the springs at this instant. Therefore, if it is assumed that the depression of the tires is the same under impact as when measured statically the maximum force can be calculated from the known static depression curve of the tire. The extent to which this assumption is justified has not been determined definitely but we believe it is qualitatively correct and that the conclusions which can be drawn from the results of the forthcoming paper may be of value as a guide to the relative effect of the tire deflection, the height of the drop and the relation of the sprung and the unsprung weight on the maximum forces to which wheels and axles as well as roads are subjected by this type of impact.

To illustrate the application of the results of the analysis as it will appear next month, if it is assumed, for example, that the height of fall from an obstruction is 3 in. the time of fall is found to be approximately 0.060 sec. and 0.075 sec. for ratios of sprung to unsprung weights of 4 and 2 respectively; in these cases a constant spring deflection of 4 in. under the weight of the sprung mass and a constant total weight are assumed. It is also found that the velocity of impact of the unsprung mass is 6.84 ft. per sec. for the first case and 5.35 ft. per sec. for the second; the kinetic energy is 4690 ft.-poundals for the first ratio of 4, and 4770 ft.-poundals for the second ratio of 2, while the impact forces are 2480 and 2590 lb. for the respective cases. Again keeping all conditions the same, except the tires, and using a ratio of sprung to unsprung weight of 4, the forces are 2050 lb. for the low-pressure pneumatic tires and 2480 lb. for the high-pressure pneumatic tires.

Thus the change of impact force due to the change in tires is about 25 per cent while that occasioned by doubling the ratio of the sprung to the unsprung weight is only about 4 per cent. Changes in the type of tire have more influence on the impact force than changes in the weight ratio.

OBITUARY

JAMES FREDERIC BOURQUIN, vice-president and general manager of the Continental Motors Corporation, Detroit, and for years an outstanding figure in Detroit's automobile industry, died, July 1, 1923, in a hospital in that city, following an operation for appendicitis, at the age of 45 years. He was born, April 9, 1878, at Detroit and, following his public and high school education, entered the University of Michigan from which he was graduated in 1904 with the degree of Bachelor of Science.

Mr. Bourquin's practical experience began in the experimental department of the Old's Motor Works, Lansing, Mich., in 1904, and was continued progressively until 1910 with this and other companies in capacities as draftsman, foreman, inspector, assistant superintendent and superintendent of manufacturing, the last being with the Chalmers Motor Co. He was active in organizing the Liberty Motor Car Co. and also contributed largely to the development of the Paige-Detroit Motor Car Co., both of Detroit; in 1911 he was general manager of the latter company.

Among the clubs to which he devoted time and enthusiasm were the Detroit Athletic Club and the Detroit Yacht Club. Also, he was a member of several clubs in Ann Arbor, Mich., and was an ardent Knight Templar. He was elected to Member grade in the Society, Jan. 30, 1911.

SPARK-ADVANCE IN COMBUSTION ENGINES

(*Concluded from p. 121*)

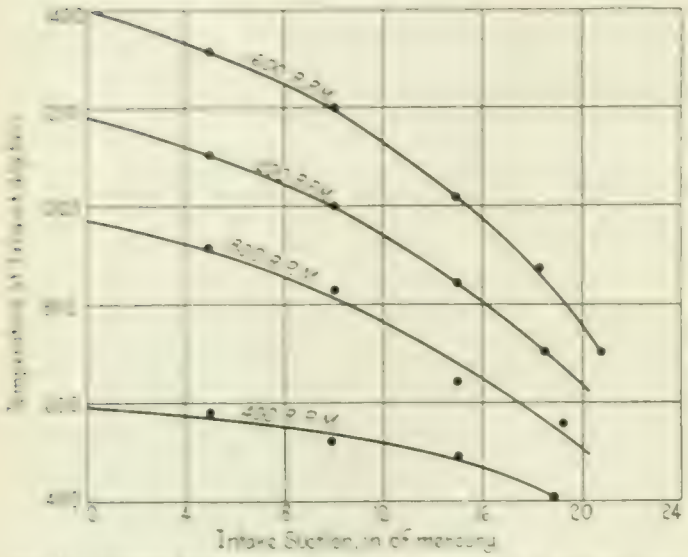


FIG. 17—CURVES SHOWING THE RELATION BETWEEN THE TEMPERATURE OF THE EXHAUST AND THE INTAKE SUCTION OR LOAD IN A CONTINENTAL SIX-CYLINDER ENGINE

The fairing of the data is done in Fig. 17; Fig. 18 is only a replotting of the faired lines of Fig. 17, with the variables exchanged.

We repeated on the Continental engine the findings on the Ford; that for all practical purposes the optimum spark-advance can be represented as the sum of two functions, one a function of speed only, the other a function of intake suction only. This follows from the fact that the curves in Fig. 15 are substantially parallel; the increase of the spark-advance for a change of the intake suction at a constant speed is shown in the lower curve that is marked intake-suction effect, in Fig. 15. An approximate empirical equation for this intake-suction effect is $a = 18\ (p_e/P_i)$. For the Ford engine the corresponding equation is $a = 13\ (p_e/P_i)$; the effect is less, probably, because the dilution at a zero intake-suction is larger in the lower-compression engine.

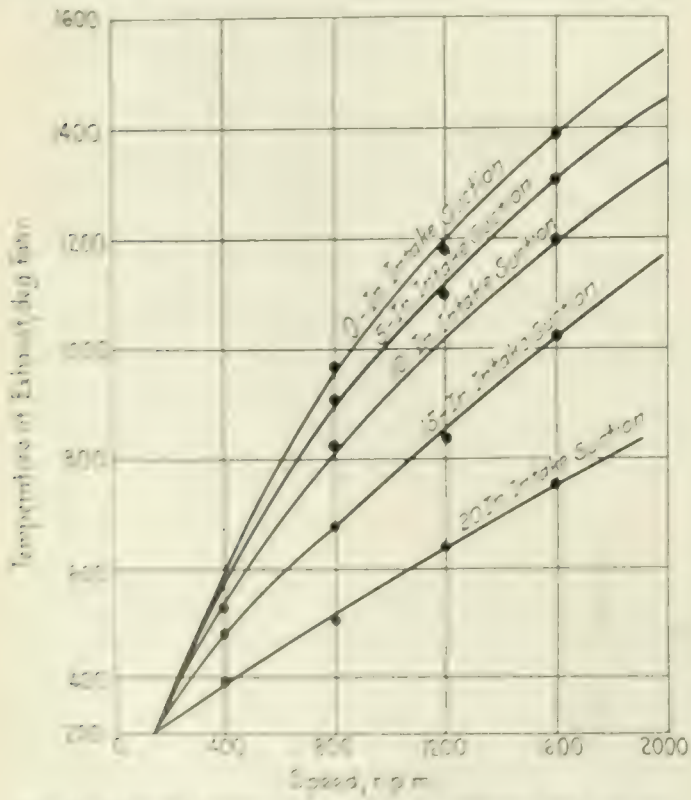


FIG. 18—CURVES SHOWING THE RELATION BETWEEN THE TEMPERATURE OF THE EXHAUST AND THE SPEED OF A CONTINENTAL SIX-CYLINDER ENGINE FOR CONSTANT INTAKE-SUCTIONS OR LOADS

The power losses from improper spark-advance and the economy losses in proportion are clearly indicated in Figs. 11 to 14. It seems, in view of these curves, that automatic spark-control by mechanically adding the two separate advances for speed and for intake suction would justify itself in improved power, economy and flexibility of engine performance. There would still be need of some hand adjustment to take care of a cold engine and of a dirty engine; but with the engine warmed up and a setting made for its internal condition all the spark-control needed to take care of the load and the speed variation would be automatic and would be done as now it is not. It would also be easy to take care of altitude effects by changing the linkage on the automatic spark-control on the intake-suction side; this would be necessary because of the greater dilution with exhaust gas at high altitudes for the same intake-suctions. The automatic device would be controlled by pressure differences, whereas the function it controls is really a consequence of pressure ratios; $p_e - P_i$ could be substituted in the mechanism for p_e/P_i.

In a scientific analysis of that component of spark-advance due to dilution with exhaust gas we need to find whether it is a matter of volumetric or of mass dilution, and whether in computing the dilution we must figure the re-expansion of the exhaust gases in the suction stroke as adiabatic or isothermal. It was to get data for this study that the readings of the exhaust temperatures in Figs. 11 to 14 and in Figs. 17 and 18 were taken. In previously discussing the dilution matter in this paper the formulas for the dilution-ratios have been derived and the probable result has been predicted that the spark-advance due to dilution will be found to be an exponential function of the mass-dilution ratio.

The volumetric-dilution ratio of the total gas to the new charge in the cylinder is $1 + (p_e/P_i)^{1/y} / [r - (p_e/P_i)^{1/y}]$; the weight-dilution ratio is $1 + ([T_i/T_e]\ [p_e/P_i]/[r - (p_e/P_i)^{1/y}]$. In these formulas r is the compression-ratio, 4.55 for the Continental engine; y is the ratio of the specific-heats, 1.33 for adiabatic and 1.00 for isothermal expansion; $1/y = 0.75$ or 1.00; T_i and T_e are the *absolute* temperatures in the intake and the exhaust manifolds; T_i is taken as $100 + 460 = 560$ deg. fahr.; absolute, because of the "hot-spotting" of the manifold; p_e and P_i are the absolute pressures in the exhaust and intake manifolds. In calculations p_e was taken as 29.4 in. of mercury and P_i as $(p_e - S)$, S being the intake suction in inches of mercury. Toward full throttle, the variation of the dilution with p_e/P_i is slow; at closed throttle the exhaust back-pressure is negligible; hence the use of the barometric pressure divided by the difference between the barometer and the intake-suction readings for p_e/P_i causes little error in the calculations. The calculated volumetric and mass-dilution ratios for the Continental engine are tabulated in Table 4.

With the values of the volumetric and the mass-dilu-

TABLE 4—CALCULATED VOLUMETRIC AND MASS-DILUTION RATIOS FOR A SIX-CYLINDER CONTINENTAL ENGINE

Intake Suction	Intake Pressure		Volumetric Dilution Ratios		Mass Dilution-Ratios: Adiabatic Speeds, R. P. M.				Mass Dilution-Ratios: Isothermal Speeds, R. P. M.			
S	P_1	p_e/P_1	Adiabatic	Isothermal	400	800	1,200	1,600	400	800	1,200	1,600
0	29.4	1.000	1.28	1.28	1.15	1.11	1.10	1.09	1.15	1.11	1.10	1.09
5	24.4	1.206	1.34	1.36	1.19	1.15	1.13	1.11	1.19	1.15	1.13	1.12
10	19.4	1.516	1.43	1.50	1.27	1.21	1.18	1.16	1.28	1.22	1.19	1.17
15	14.4	2.042	1.60	1.81	1.43	1.36	1.31	1.27	1.49	1.40	1.35	1.31
20	9.4	3.127	2.07	3.20	1.93	1.83	1.72	1.66	2.44	2.27	2.12	2.02
22	7.4	3.975	2.62	7.92	...	...	...	...	...	...	...	...

tion ratios in Table 4, and the optimum spark-advances from the faired curves in Figs. 15 and 16, curves of spark-advance against dilution-ratios for constant speeds have been plotted in Fig. 19 on logarithmic cross-section paper. If dilution had an effect that is separable from that of speed or turbulence, the family of curves for the different constant speeds in these charts should be a set of parallel lines of constant vertical offset from each other. This is obviously not the case when we measure dilution volumetrically; it is approached closely when we measure dilution by mass ratio and is given better by the adiabatic than by the isothermal assumption of the law of re-expansion of clearance, or exhaust, gases on the suction stroke. Further, the dashed straight lines of the two charts at the right show that the increase of spark-advance due to dilution is approximately proportional to the cube of the mass-dilution ratio; or, in other words, the combustion rates vary inversely and the explosion-times directly as the cube of the adiabatic mass-dilution ratio of the total gas to the new charge. If in plotting the curves at the extreme right the unfaired data of the optimum spark-advances, taken directly from Figs. 11 to 14, is used, the agreement with the cube law is rather improved; hence the use of our faired curves of spark-advance has not been responsible for this suggested law of the action of dilution. This cubic law, of course, is merely suggested, not proved, by such a slender basis of data as is used here; but it was to be expected on general grounds and has been found here to account for the facts, as well as any simple hypothesis that has been tried.

Evaluation of the Turbulence Factor

Since it is now possible to eliminate the dilution or intake-suction factor from the spark-advance, the turbulence factor may be evaluated. This has been done in two ways. First, as was done in the case of the Ford, all the spark-advance data were reduced to values for a zero intake-suction at the various speeds. Fig. 16 shows this reduction for the Continental engine. Then values of R/a_o, or a zero intake-suction, were plotted against R, giving the lower straight line in Fig. 20. The equation of this line is $R/(a_o) = 22\ (1 + 0.001R)$; or by inversion, a_o is equal to $0.0455R/(1 + 0.001R)$. This corresponds to an explosion-time in the combustion-chamber without turbulence, but with the dilution existing at a zero intake-suction, of $(2/9) \times 0.0455 = 0.0101$ sec. This may be compared directly with the corresponding value for the Ford engine of 0.0230 sec.; and the turbulence factor, found in the same way, comes out the same, 0.0010, for both engines. This is interesting as both are of the L-head type and of rather similar dimensions. The much quicker explosion-time for the Continental engine may correspond to a better shape of the combustion-chamber, a better placing of the spark-plug, better carburetion due to the hot-spot and the like and the higher compression-ratio.

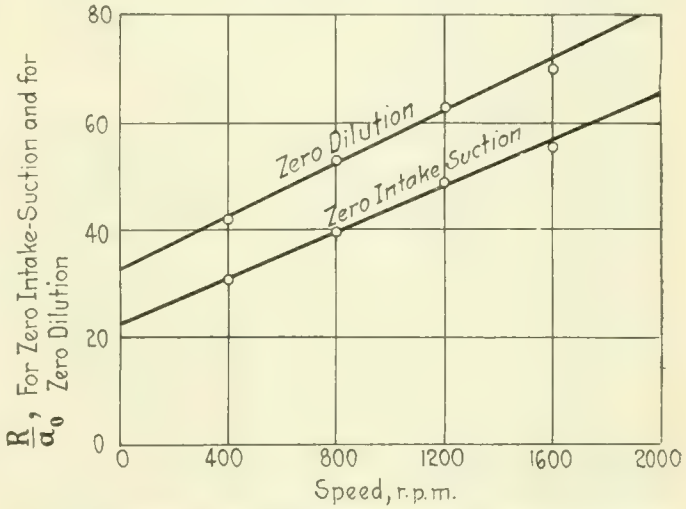


FIG. 20—CURVES OF ZERO DILUTION AND ZERO INTAKE-SUCTION AT VARIOUS SPEEDS

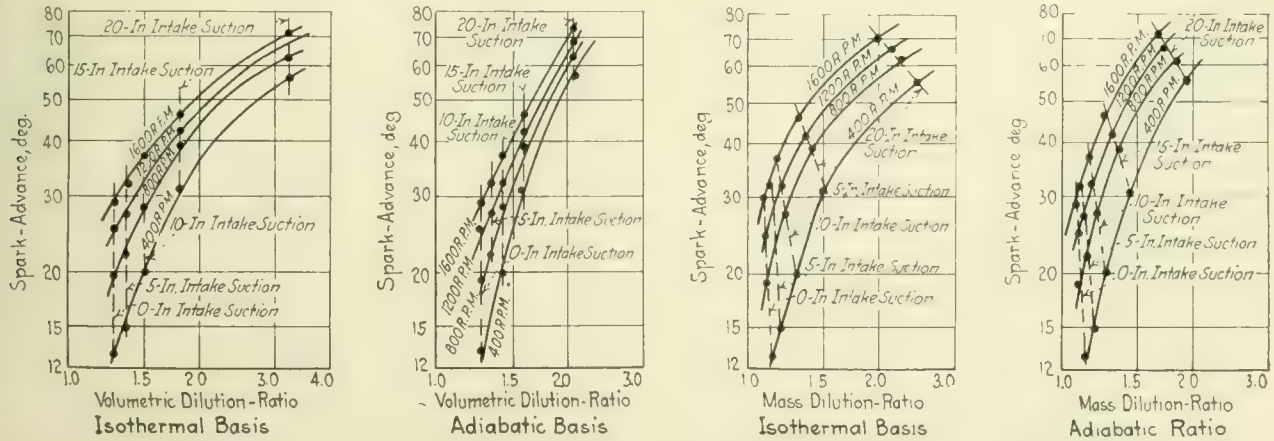
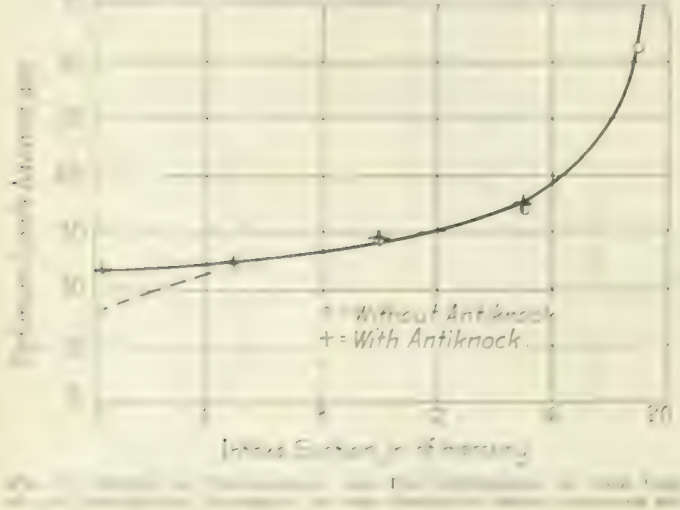


FIG. 19—CURVES SHOWING THE RELATION BETWEEN THE SPARK-ADVANCE AND THE VOLUMETRIC AND MASS DILUTION-RATIOS ON THE ISOTHERMAL AND ADIABATIC BASES

It is possible also in the case of the Continental engine to eliminate the case of zero dilution. Assuming the same law of the slowing-up of the combustion by admixture dilution, the spark-advances for the Continental engine at zero dilution are 9.5 deg. at 400 r.p.m., 16 deg. at 800 r.p.m., 19 deg. at 1200 r.p.m., and 25 deg. at 1600 r.p.m. See the right half of Fig. 19 for this relation to zero dilution, or a 1.00 dilution-ratio.) The upper straight line in Fig. 20 plots R vs. of these zero-dilution values against R. Its equation is R vs., or zero-dilution, $= 12.5 + 1 = 0.00075R^2$ and corresponds to the zero-dilution $= 0.0308R^2 + 1 = 0.00075R^2$, and the explosion-time with zero dilution and zero turbulence of $2 \times 0.0308 = 0.0068$ sec.

It will be noticed that the value of the turbulence factor, the coefficient of R in the denominator of the spark-advance equations, is not the same when the equation is found for a zero intake-suction as it is when found for zero dilution. This comes from the fact that the dilution at a zero intake-suction is not constant as the speed changes, but is less at higher speeds.

Further, it will be noticed that the explosion-time in the engine cylinder, even with some dilution but without turbulence, is of the order of from 0.02 to less than 0.01 sec. These values are conspicuously smaller than the values quoted early in the paper for bomb experiments, which ran around 0.05 to 0.06 sec. for maximum-power mixtures. The reason for the difference is partly in the size of the combustion-chamber of the engine as compared with the bombs; on this account alone the explosion-times in the engine, in view of the empirical square-root law of the distance for the time of flame travel, should be from 0.50 to 0.75 times the explosion-times in the bombs. The main factor making the explosion-times less in the engines than in the bombs, even without turbulence, is the temperature. The Continental engine gets its charge at about 560 deg. fahr., absolute. Compression multiplies this temperature by the γ-1 power of the compression-ratio, or by about 1.65, making the temperature preceding ignition about 930 deg. fahr., absolute. As the combustion speed is approximately proportional to the cube of the temperature preceding ignition, the combustion-rate is increased by adiabatic compression about 4.5 times over what it would be at the intake temperature and about 5.3 times over what it would be at the mean temperature. Even without turbulence, then, we might expect the explosion-times in automotive engines to be of the order of 1/5 to 1/10 of what they are in the bomb experiments cited. The effect of turbulence



is to offset the slowing-up of the combustion due to dilution, rather than to cause the explosion-times in the engine cylinder to be less than in the experiments on sizable bombs in laboratory work. Of course, turbulence remains highly important in high-speed engines.

In the experimental work on the optimum spark-advance on the Continental engine, shown in Figs. 11 to 14, we did not get the data at full throttle but went only as close as the 5-in. suction. This was because of the detonation that occurred at pressures lower than the 5-in. intake-suction. We investigated later what would happen in the presence or absence of detonation. The work was at 600 r.p.m. The results are shown in Fig. 21. We ran through the whole throttle range, 0, 5, 10, 15 and 19-in. intake-suctions, without anti-knock and then with it. The dose of anti-knock, tetraethyl-lead, was 5 cc. to 2 qt. of gasoline, or 20 times the dosage usually required or advised for knock suppression.

Discussion of Results

The results are extremely interesting. For any intake-suction large enough of itself to stop detonation by throttling or pressure-reduction, the presence of anti-knock, in a dosage 20 times the usual value, does not change the optimum spark-advance at all, according to our data; hence it does not affect the explosion-time or the reaction-velocity of combustion. The accuracy of determining the optimum spark-advance is perhaps ± 2 deg.; on a 30-deg. advance this is an accuracy in the explosion-time of ± 7 per cent. The usual dosage of anti-knock, then, cannot alter the reaction-rate by more than 0.33 per cent. The hypothesis that anti-knocks stop detonation by changing the reaction-rate of combustion seems to have here a considerable jolt. It does stop detonation, however; and further, with detonation stopped, the spark-advance-intake-suction curve is smooth and continuous to the zero intake-suction; and combustion follows a single set of laws, those of normal non-detonating combustion, over the whole throttle-range. In the absence of anti-knock, combustion seems to follow two laws, as indicated by the dotted line in Fig 21; the normal laws for intake-suctions greater than 5 in. in this case; and the abnormal laws, involving detonation, at between zero and a 5-in. suction. When detonation occurred the torque also was perceptibly less than when it was suppressed.

In summarizing, we have shown that spark-advance is a relation of the explosion-time to the speed of rotation of the engine. From a simple hypothesis about flame speed, combined with the geometric shape of the combustion-chamber, we have deduced that one-half the rise of pressure of an explosion should occur at or near three-quarters of the explosion-time; and we have checked the conclusion on pressure-time curves of both bombs and engines. We have shown that for an optimum spark-advance the half pressure-rise, or three-quarters of the explosion-time, should occur at the dead-center position of the piston. Hence, we have made it possible, through the experimental determination of the optimum spark-advance in an engine in operation, to calculate back to the explosion-time as it actually takes place in the engine. This opens a wide field for experimental work in finding the effects of the mixture-ratio, the temperature, turbulence, dilution with dead gas and the like,; the shape and the size of the combustion-chamber and the like; with a possibility, hitherto not known, of finding numerical values for the effects of turbulence, dilution and the like that may put combustion-chamber design of the future on a quantitative basis.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between June 10 and July 10, 1923. The various grades of membership are indicated by (M) Member, (A) Associate Member; (J) Junior (Aff) Affiliate (S M) Service Member, (F M) Foreign Member (E S) Enrolled Student.

BAKER, B. F. (S M) automotive engineer, Rock Island Arsenal, Rock Island, Ill., (mail) 2652 Redwood Avenue, *Davenport, Iowa.*

BARTUSKA, JOHN F. (J) engineer, Marmont Mfg. Co., *Chicago,* (mail) 3718 North St. Louis Avenue.

CARLOS, MENELEO G. (E S) student, Cornell University, *Ithaca, N. Y.,* (mail) 123 Quarry Street.

DEGENER, PAUL A. (M) president, Rochester Motors Corporation, 233 Broadway, *New York City.*

DUNBAR, FRANK (E S) student University of Cincinnati, *Cincinnati,* (mail) 94 West McMillan Street.

DUNBAUGH, GEORGE J., JR. (A) secretary, Champion Mfg. Co. 74th Street and Kimbark Avenue, *Chicago.*

GILBERTSON, GEORGE B. (E S) student, University of Minnesota, *Minneapolis,* (mail) 939 18th Avenue, South East.

GILLET, CHARLES C. (A) district sales manager, Seamans & Cobb Co., 4612 Woodward Avenue, *Detroit.*

GLEISEN, D. (M) manager of Eastern division, Hyatt Roller Bearing Co., Harrison, N. J., (mail) 829 Pavonia Avenue, *Jersey City, N. J.*

GRATWICKE, WALTER (M) engineer, British Aluminum Co., Ltd., 592 King Street, West, *Toronto, Ont., Canada.*

GREY, EUGENE H. (M) general superintendent of motor equipment, Gulf Refining Co., *Pittsburgh,* (mail) P. O. Box 1214.

HANNING, JAMES ROWLAND (E S) student, University of Toronto Toronto, Ont., Canada, (mail) 119 Agnes Street, *Oshawa, Ont., Canada.*

HOELER, WILLIAM (M) manager and superintendent of body shop, International Motor Co., New York City, (mail) 100 West Polk Avenue, *Corona, N. Y.*

HUKILL, H. D. (M) in charge of automotive division, Westinghouse Air Brake Co., *Wilmerding, Pa.*

HULTON, RALPH (J) (Det.) branch manager, Lovejoy Detroit Co., 39 West Warren Avenue, *Detroit.*

IBGENS, F. T. (J) student, Purdue University, Lafayette, Ind., (mail) 1748 Leer Street, *South Bend, Ind*

JESSUP, C. P. (E S) student, Sheffield Scientific School, Yale University, New Haven, Conn., (mail) 15 Arch Street, *Norwalk, Conn.*

JUDD, IRVING H. (M) chief draftsman, Whitehead & Kales Co., River Rouge, Mich., (mail) 439 Temple Avenue, *Detroit.*

LINDEMAN, EDWARD H. (M) sales engineer, Perfection spring division of Eaton Axle & Spring Co., East 65th Street and Central Avenue, *Cleveland*

LOGAN, G. L. (J) technical service, Packard Motor Car Co., *Detroit,* (mail) 1724 Philadelphia Avenue, West.

LUIGGI, MARIO LUIGI (F M) mechanical and civil engineer, R. Garrett & Sons, Leiston, England, (mail) 56 East 87th Street, *New York City.*

MACDONALD, W. W. (M) chief engineer, MacDonald truck division of the Union Construction Co., Foot of 14th Street, *Oakland, Cal.*

MACGREGOR, B. N. (A) cable sales, Packard Electric Co., *Warren, Ohio.*

MATSUMOTO, AKIYOSHI (J) engineer, Dodge Bros., *Detroit,* (mail) care of Mr. Kaneko, 1420 Washington Boulevard.

MUNROE, WILLIAM O. (M) vice president, Standard Steel & Bearings, Inc., *Philadelphia,* (mail) 6114 Oxford Street.

MURAKAMI, YOSHI-AKI (F M) works manager, Ishikawajima Shipbuilding & Engineering Co., Ltd., *Tokyo, Japan,* (mail) Ishikawajima Auto Works, No. 3 Tomikawa-cho Fukagawa.

NOELKE, H. M. (J) experimental assistant in engineering laboratory, International Motor Co., 252 West 64th Street, *New York City*

PHILIP, CHARLES W. (J) chief engineer, Philip Motor Co., 143 Geary Street, *San Francisco.*

PLATZ, HENRY A. (E S) student, Michigan Agricultural College, East Lansing, Mich., (mail) 201 Jones Street, *Lansing, Mich.*

RABILOUN, EDWARD J. (A) service supervisor, Reo Motor Car Co. of New York, *New York City,* (mail) 2505 University Avenue

REED, NEWTON L. (J) manager of truck department Crew Levick Co., *Philadelphia,* (mail) 3929 Locust Street.

RHAME, P. W. (A) instructor, University of Minnesota, *Minneapolis,* (mail) 941 14th Avenue, South East.

SKINNER, ARTHUR A. (A) sales manager, Leece-Neville Co., *Cleveland,* (mail) 13,309 Sixth Avenue, East.

SMALLEY, J. SHEPARD (M) chief engineer, A. Meister Sons Co., 360 North Michigan Avenue, *Chicago.*

STEELE, FLOYD HARRY (A) factory manager, Handy Governor Corporation, 3021 Wabash Avenue, *Detroit.*

SULLIVAN, EDWARD C. (A) sales engineer, Flint Varnish & Color Works, Flint, Mich., (mail) 3-231-2 General Motors Building, *Detroit.*

VOGEL RALPH EMERSON (E S) student, University of Illinois, Urbana, Ill., (mail.) *Princeville, Ill.*

WACHTLER, WILLIAM B. (A) manager, Eastern division of the Hyatt Roller Bearing Co., *Harrison, N. J.*

WATSON, CLIFFORD E. (J) Laurel Cement Brick Co., Laurel, Conn., (mail) 1606 Boulevard, *New Haven, Conn.*

WETHERBY, W. G. (A) secretary and treasurer, Handy Governor Corporation, *Detroit.*

WILLIAMS, FRANCIS (A) sales manager, Gardner Waern & Co., Pty. Ltd., Flinders Street, Melbourne, Australia, (mail) care of S K F Industries, 115 New Montgomery Street, *San Francisco.*

Applicants *for* Membership

The qualifications for membership required between June [illegible] and given below. The members of the Society are asked to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

[illegible], S. S., factory manager, Ternstedt Mfg. Co., *Detroit.*

[illegible], A. W., manager of sales, electric steel department, Eastern Steel Castings, Inc., *Newark, N. J.*

[illegible], [illegible], [illegible], Seaboard & Gulf, *Boston.*

[illegible], [illegible], experimental foreman, Phelps Light & Power Co., [illegible], Ill.

[illegible], [illegible], [illegible], Ternstedt Mfg. Co., *Detroit.*

[illegible], [illegible], [illegible], manager, Standard Steel and Bearings, Inc., [illegible], Conn.

[illegible], [illegible], [illegible], [

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIII September, 1923 No. 3

Chronicle and Comment

Letter Ballot on Standards

As a result of the Society letter ballot on the adoption of standards, the recommendations approved at the Standards Committee Meeting at Spring Lake were confirmed and have been issued to the members in final data-sheet form. The results of the letter ballot are given on p. 246.

Annual Meeting Date Announced

ANNOUNCEMENT was made last spring that the next Annual Meeting of the Society would be held in Detroit. The dates of this meeting have now been set definitely as Jan. 22-25 to coincide with Automobile Show week in Detroit. This arrangement will enable members who attend the meeting to inspect passenger cars and trucks of the latest design, many of which will come direct from the New York Show on the way to Chicago. Thus the advantage of holding the Annual Meeting simultaneously with a representative exhibit of motor vehicles will be preserved, conflicts with numerous dealer, factory and association functions will be avoided, and the location of the meeting will be nearer the production center of the industry.

International Ball Bearing Standards

A RECENT report received from Zurich, Switzerland, indicates that considerable progress was made at the International Conference of Secretaries of national standardizing bodies held there on July 9 toward the international standardization of ball bearings, particularly the radial type. The Zurich conference on ball bearings was attended by the Secretaries of the Swiss, Swedish, German and American national standardization bodies and by delegates of Swedish, German and American Sectional Committees.

Although the report is preliminary only, it indicates that those attending the conference agreed upon the diameters, widths, and corner radii for radial type bearings in light, medium and heavy series. If the extra wide type of radial bearings is needed by the foreign countries, the S. A. E. Standards will be considered. A proposal is to be prepared for tolerances for bores, diameters and widths based on the unilateral system, the bore and diameter tolerances following approximately those proposed by the American Sectional Committee in March, 1922, and the width tolerances following the present Swedish practice.

The latest German proposal for thrust ball bearings was recommended, extended to include 600 mm. diameter and an extra heavy series, the tolerances for all diameters to follow those for the radial bearings. The Sectional Committees of England and America are asked to submit proposals for inch size bearings.

Pennsylvania License Law Unconstitutional

AN opinion that the Pennsylvania engineering licensing act is unconstitutional has been rendered by a judge in the Court of Quarter Sessions of Monroe County of that State. The judge interpreted the law as conflicting with the constitution of the State on the technicality that it deals with two professions in the same act, a condition forbidden by the State constitution. He also contended that the licensing act violated the Fourteenth Amendment of the Federal Constitution in that it shows discrimination in the exemption of certain classes. This action will be of interest to members of the Society who practise in the State of Pennsylvania, and may also be expected to influence legislation and the enforcement of laws in other States in which similar statutes are contemplated or are already in force.

Keeping Pace with Progress

SECTION meetings activity reopens with the arrival of September and the fall season. A calendar of the meetings scheduled during the coming month will be found on p. 252. Eight-in-line engines, headlamp glare and wheel-alignment are the topics to be discussed by three of the Sections, the members of one of the other Sections will visit a large passenger-car factory and another Section opens its session with sports and a social evening.

Meetings of the Sections have gained in value and importance with the expansion of the parent Society. Attendance is often as large as at the national technical sessions; papers presented have equal status with those read at the parent Society meetings and receive the same consideration in THE JOURNAL. Discussion at Section meetings is especially productive of valuable information because of the presence of a larger group of specialists at the local meetings and the longer discussion period

that is usually available. Section meetings broaden one's acquaintance and, moreover, they are the equivalent of a course of post-graduate lectures in automotive engineering. Form the habit of attending them and you will derive full value from your membership in the Society.

Promoting Production Efficiency

MACHINE tools and production methods that are of particular interest to manufacturing executives will be discussed at the Production Meeting of the Society in Cleveland next October. This meeting is intended to serve as a national clearing-house where factory managers may exchange ideas regarding valuable shop experience and discuss production problems to their common benefit and for the general good of the industry. Over 200 production men took advantage of the opportunity offered by the meeting in Detroit last October and voiced their approval of it as a means of perpetuating the cooperative spirit among factory experts that was engendered by the war. Shop kinks used to be guarded jealously by their originators, but the national emergency destroyed that selfish attitude. Exchange of practical shop information is now fairly universal and the Production Meeting merely fosters this exchange to a greater degree and on an organized basis. If you have material that you wish to place before the Cleveland meeting be sure to call it to the attention of the New York Office at once. Do not fail to mark the dates on your calendar and come to Cleveland Oct. 25 and 26.

Standards Committee Meetings

MEETINGS of Divisions and Subdivisions of the Standards Committee are being planned to start about the middle of September in most cases, according to the progress that is made with the work before each group. The time and place of all meetings will be arranged so far as possible so that all Division and Subdivision members can attend with the least expense and time. Regular notices will be sent to all members sufficiently in advance of meetings so that they can arrange accordingly.

It is expected meetings will be arranged for the Axle and Wheels, Ball and Roller Bearings, Electric Vehicle, Engine, Lighting, Lubricants, Passenger-Car Body, Screw Threads, Tire and Rim, and Transmission Divisions. A meeting of the Motorboat Division has already been scheduled at the Society's Offices in New York City on Thursday, Sept. 27, at 2 o'clock.

Better Brakes Assured

REGARDLESS of the many derogatory comments that have been made on four-wheel brakes, their introduction is producing one commendable result. It is stimulating engineering investigation that eventually will increase the effectiveness of brakes in general. Practically as much thought is being expended on rear-wheel and transmission brakes as on the perfecting of satisfactory four-wheel systems. Deceleration is now becoming as important in comparisons of performance of automobiles as has been in the past. It is fortunate that this attitude should prevail at a time when public opinion is stirred by the rising number of highway automobile accidents. Careless and irresponsible drivers are beyond the influence of the automotive engineer, but he can contribute to the reduction of accidents by providing motor cars with means of deceleration that at least are as highly developed as those of acceleration. This he appears to be doing, and the introduction of four-wheel brakes deserves a large share of the credit for stimulating his interest in this phase of highway safety work.

Agitation for compulsory periodic brake-inspection has begun in many parts of the Country. Whether such measures will conduce to greater safety lies outside the province of this comment, but they do serve as a warning to automotive engineers that inefficient braking systems will not be acceptable to the motor-buying public in the future. Operators will pay more attention to ease of adjustment and equalization. Narrow linings, which wear rapidly and need to be replaced frequently, will be decidedly unpopular; inaccessible adjustments of linkage and bands will be condemned. Efficient brakes that can be kept efficient with the minimum of attention will be an important factor in influencing motorists in their selection of 1924 models.

1922 Transactions

WHEN this issue of THE JOURNAL went to press Part I of the 1922 TRANSACTIONS was in the hands of the binder, and it is expected that copies will be sent the latter part of this month to those of the members who have requested them. This part, which is the first of Vol. 17 of THE TRANSACTIONS, is a book of approximately 920 pp. and contains such of the papers presented at the 1922 Annual Meeting of the Society, together with those of the papers presented at Section meetings and printed in THE JOURNAL for the first 6 months of last year, as were deemed of sufficient engineering value by the Publication Committee to be reprinted in the permanent records of the Society.

Following the arrangement that was first used in Part II of the 1921 TRANSACTIONS, the 31 papers constituting the present volume are grouped according to subjects irrespective of where the papers were presented instead of following the earlier arrangement in which the papers at the National meetings of the Society came first, with the Section papers following according to the alphabetical arrangement of the names of the Sections. The subjects covered include fuels and engines, lubrication, the development of air-cooled cylinders and engines, testing brake-linings, tractors, metallurgical subjects, body design and dimensions and roads and highways. To supplement the information presented in the various papers, numerous illustrations have been used and in several instances folding inserts have been employed where it was impossible to reduce tables or illustrations to the size of THE TRANSACTIONS' page without considerably impairing their value.

Work on Part II of the 1922 TRANSACTIONS has already been begun and the date for the appearance of this volume has been tentatively set as Dec. 31, 1923. Copies of this part will be sent only to members who send in their orders by Nov. 5. There is no charge for this volume to members who paid dues for the first half of the fiscal year beginning Oct. 1, 1922. For the convenience of the members in ordering this part of THE TRANSACTIONS, an order blank will be found in the advertising section of this issue on p. 83.

Trolley Buses and Flexible Vehicles for Street Railway Service

By William P. Kennedy[1]

Metropolitan Section Paper *Illustrated with* Photographs and Drawings

THE author surveys some of the general conditions prevailing in the street-railway field and the prospective development of a new type of service, in discussing the necessity for closer cooperation between the engineers of the automotive industry and the operating organizations of the railways, the idea being to develop flexible transportation-equipment that will coordinate with the operation of present railway-transportation facilities and to promote the utilization, wherever feasible, of railway power-supply in the employment of flexible bus-type equipment in supplementing and extending railway-organization service.

Changing conditions are outlined, the influences tending toward flexible equipment are stated, and the differences of engineering practice pertaining in the railway and automotive fields are commented upon to show wherein railway and automotive engineers can cooperate.

The trolley bus is considered in some detail as being one solution of the problem, and the Mercedes Stoll, the Filovia and the Max Schiemann systems of operation are described. Present national practices of operation with various types of equipment are mentioned, and a description of dual-power bus-equipment and independent buses having electrical transmissions, with comment thereon, is included. Body and chassis requirements are enumerated, the permanency of public-service transportation and prospective street-railway business is considered, and the requirements of so-called "flexible" equipment are treated at length.

THE general purpose of this paper is to make evident the necessity for closer cooperation between the engineers of the automotive industry and the operating organizations in the street-railway field, with the idea of solving more effectively the particular problems of the latter in their endeavor to develop flexible transportation-equipment to coordinate with the operation of their rail-transportation facilities and further, to promote the utilization wherever feasible of railway power-supply in the employment of flexible bus-type equipment in supplementing and extending railway-organization service. It is necessary, therefore, to survey some of the general conditions prevailing in the street-railway field, and the prospective development of a new type of service within the near future.

Changing Conditions

In 30 to 40 years of development of power-operated street-railway passenger-transportation equipment, there has been gradual progress in meeting a constantly increasing demand from the earlier lighter types of vehicle and rail equipment, inherited from the preceding horse-car service, to the more capacious forms of equipment required for mass transportation in densely populated cities, and the collateral development of the heavier long-distance Pullman-type vehicles used in interurban service. During the greater period of this progress, there has been a constant increase in the weight of equipment employed. In recent years, however, there has been a marked endeavor to reduce these weights in view of the improvement in structural materials, developed largely by the demands of the automotive industry. This recession has been forced by the changing economic conditions affecting the cost of operation and, more recently, by the appearance of competition in the field in the form of the motorbus.

When we review in perspective the various developments that have taken place in public-service utilities over a period of 50 years or more, we are able to realize the relative stability of each division of these utilities and thus to form sound judgment as to the permanency of their foundation, particularly in the equipment employed in each of these divisions, which are railroad freight and passenger service, public lighting, the generation and distribution of energy for power purposes and street-railway systems for local passenger-transportation. The permanency of these several industries depends largely upon the invention and application of devices that tend to expand their application territorially, or that supply the public with means facilitating a more broad utilization of the service rendered. This implies an urgent necessity on the part of public-service organizations to foster and to develop the employment of such devices. On the other hand, the instability of these public utilities can be measured by the likelihood of the growth of competitive developments in the form of devices that can be procured by competitive operators and employed with much less investment and that may render a somewhat similar if not equivalent service to the user.

In such a comparison it will be realized that long-distance railroad-service as a public utility is almost impregnable, and that public-lighting utilities are so substantially entrenched and can be operated so economically that competition is negligible. Power generation and distribution on a large scale, as yet in its early stages, is similarly on a secure foundation; and it may be observed that the lighting and power industries have been developed and will continue to progress under the conditions of competition that have been the means of keeping them in an aggressively active condition.

Influences Tending Toward Flexible Equipment

In contrast with the foregoing statements, the street-railway industry has grown up under the fallacious belief that it is equally as stable as the railroad industry, and the development of its equipment seems to have progressed with the absence of any thought of possible competition. Unfortunately, its permanency is much more dependent upon a number of isolated and local conditions, being subject to political and community requirements, and monopolizing to a large extent the public

[1] M.S.A.E.—President, Kennedy Engineering Corporation, New York City.

of a minimum weight for a maximum performance. The automobile is a power vehicle exemplifying characteristics in marked contrast with the street car that was developed for an entirely different service when the number of passengers and the speed of the machine are taken into consideration. Nevertheless, the fact is apparent that the changing demand in public passenger-transportation encourages a closer cooperation between the two schools of engineering thought existing in these different fields to combine in developing the best that can be procured to meet these new requirements.

The railway engineer has been handicapped from a progressive standpoint by the absence of the necessity of meeting competition. There has been a comparatively limited output in machines for his industry, reducing the possibility of mass production; consequently and of necessity, there have been limited sources from which he could procure competitively developed equipment. His power units came from two or three large manufacturing organizations providing other varied products, which naturally limited any tendency to progress rapidly toward lighter and more flexible machines. Likewise, his sources of body structures were limited and confined to comparatively few manufacturers, with the obvious handicaps that changes from previously established standards were difficult to obtain. Furthermore, the necessity for caution in providing against accident and damage in rendering public service enforced upon him a conservatism from which the automotive engineer has been almost entirely free; obviously, it must be recognized that a readiness to rise up quickly and provide radically different forms of vehicles to meet emergencies in offsetting unforeseen competition was not to be expected. Now, however, after a period in which competing types of vehicle in the form of motorbuses have been permitted to intrude upon his business field, with the consequent loss of the most easily secured and profitable part of his sources of revenue, his attitude must necessarily change and he must proceed at once to provide an acceptable solution in a new form of equipment to enable his industry not only to recover its lost business but to reach into new fields for expansion and profit.

Railway and Automotive Cooperation

He cannot be expected to be entirely familiar with all of the new equipment available to him of which he might make use, nor has he had experience in the use of such new equipment as will enable him to provide safely for the contingencies that are inherent to public-service passenger-transportation. On the other hand, while the automotive engineer may be entirely familiar with the variety of forms and possible uses of the mechanical and power units that have been developed within his field, he has not acquired by experience any complete knowledge of the service demands to which such mechanical and power units may be subjected under the arduous services required in rendering the continuous performance demanded in public-utility service. Hence, there is good reason for a give-and-take attitude in the meeting of these different minds when concentrated in common upon the new problems in question, and it must be conceded that such an intimate collaboration would certainly be productive of advantage to the industries represented by both parties.

The particular fundamental fact to be borne in mind is that the vehicles which would best serve these purposes would be those that could utilize partly, if not entirely, the power-supply and distribution system available for such employment existing within the street-

Fig. 1—A Type of Trolley Bus That Has Been Developed for Use in England

railway organizations. By such means, existing properties representing a large investment can be preserved and applied to a much greater range of service activity than was ever contemplated by the founders of these public-transportation organizations.

A general specification of the desired requirements of street-railway organizations in providing transportation service through flexible vehicle-equipment will be found in the report on this subject of a committee of the New England Street Railway Club dated Feb. 2, 1922, extracts from which are given in Appendix 1.

The Trolley Bus As One Solution

Obviously, the first step in this general direction would be a broader application of the trolley bus as constituting a means for the solution of some of the existing railway-organization problems. It cannot be expected to solve all these problems, but it must be admitted that the desirability of its use in many cases is indicated clearly.

The use of the trolley buses in European countries has been covered in a very comprehensive way by H. L. Andrews, of the railway and traction-engineering department, General Electric Co., who, in an article entitled The Possibilities of the Trackless Trolley,[3] points out that

> European countries have for a great many years successfully operated trackless trolleys. In 1920 there were in England 20 companies with more than 100 miles of trackless-trolley installations operating or authorized, while Italy had 8 companies comprising a total of 43.5 miles of route, and Germany had 8 installations for passenger and freight traffic. France, Sweden and Austria have a number of installations in successful operation.

The three general systems in use in Europe are the Mercedes Stoll, the Filovia and the Max Schiemann, all of which differ in the method of drive and in the method of collecting current.

The Mercedes-Stoll system is essentially a four-wheel drive, although two-wheel-drive installations have been made. The driving motor is built into and is a part of the driving wheel. The control is arranged to give six speeds and three electric-brake positions. When used with the two-wheel drive, the motors are connected in series for the first three points and in parallel for the last three positions. The arrangement for the four-wheel drive differs from the two-wheel drive only in having the two front-wheel or the two rear-wheel motors connected in series.

The collector used with the Mercedes-Stoll system is of the overrunning or carriage type. The current collector at the trolley end is composed of a frame having two small grooved wheels with ball bearings on each side, one pair running on each wire. A cable with a double wire hangs down from the center of this frame or trolley and has a weighted pendulum that keeps the wheels well pressed down on the wires. This collector allows considerable movement from the trolley wire, and extreme movement is taken care of by a cable and a reel on the car that allows a 30 to 35-ft. radius from the center of the trolley. When vehicles operating in opposite directions meet, the drivers exchange collectors and plugs, which are detachable readily and within easy reach.

This system for the collection of current has proved successful, but has the disadvantage of requiring special overhead-construction and, in case the carriage leaves the trolley wire and falls to the street, it is damaged considerably. The arrangement of mounting the motors directly on the driving axle requires low-speed motors with a low efficiency and a great weight. The maintenance on the motors is higher than if they were spring supported, due to the fact that they receive all of the hammer blows from the road. For the most part these trackless trolleys weigh approximately 6048 lb., less the load, and have a seating capacity of 25 persons. In some few installations larger cars weighing over 11,000 lb., complete, are used. One installation is equipped to handle motor and trailer cars; the motor cars having a seating capacity of 22 and the trailer cars of 20 people.

The Filovia system, which is in operation on more than 40 miles of route with eight different companies, has proved very successful. This system adheres to a two-motor drive, each motor being mounted on the chassis and geared to a jack shaft on which is mounted a sprocket wheel. Transmission of power to the rear wheels is by a chain drive. Each car is equipped with two 12-hp. motors. The collectors used are similar to those described with the Mercedes-Stoll system, except that they are connected to the bus by a rigid pole.

The Max Schiemann system has been employed extensively in Germany for both passenger and freight service. There are eight or more installations, three of which are strictly passenger service, four are entirely for freight and one handles both freight and passengers. This system uses a two-motor drive, each motor being

Fig. 2—Another Example of English Equipment
Two Motors, Each Driving the Two Wheels Independently, Are Used. The Tractor Arrangement Provides a Floor for the Car That Is 14 In. from the Ground. All of the Load Is Carried by the Rear Axle Since It Is Located Midway under the Load-Carrying Portion of the Vehicle

[3] See *Electric Railway Journal*, Dec. 4, 1920, p. 1136.

Fig. 1—The Type of Trolley Bus Used in Paris, France

mounted on the truck chassis and geared to a jack shaft by bevel gears. Power is transmitted to the rear wheels by a chain drive. The three methods of collecting current used with this system are (*a*) two trolley poles under-running on the trolley wire; (*b*) one trolley pole with a double head carrying two trolley wheels; and (*c*) an over-running carriage as described under the Mercedes-Stoll system. This last method of collecting current has not produced good results, due to the damage resulting from the carriage leaving the trolley wire.

National Practices

English practice differs somewhat from any of the three systems previously described. Two motors are used, each being mounted on the truck chassis and connected to a jack shaft through worm gearing. The jack shaft carries a sprocket wheel, and power is transmitted to the

driving wheels by a chain drive. Two examples of English practice are shown in Figs. 1 and 2. This practice of using two motors, and the method of operation has been changed somewhat in the more recent installations, particularly the one in Shanghai, China. On these buses, two motors that are mounted directly on the chassis are used; but the jack shaft and the chain gearing are omitted, the motors being direct-connected to the driving axle through worm gearing, and each motor drives one of the rear wheels. English operators who have used the gasoline-propelled bus more extensively than we have until recently in this Country, both independently of their railway systems and as feeders to their established lines, have stated that the gasoline-propelled bus, so far as it has been developed, cannot be operated at the same cost as the street car and that they are not well adapted for handling peak loads. But they have found the gasoline bus well suited to operate as feeders or to connect-up existing street-railway routes.

The Paris transportation-system is now operating trolley buses of the type shown in Fig. 3 as extensions of the trolley lines in rapidly growing suburban sections.

In the United States and in Canada, recent installations have been made on Staten Island (See Fig. 4) and in New York City; Baltimore (See Fig. 5); Richmond, Va.; Minneapolis (See Fig. 6); Los Angeles; Toronto (See Fig. 7), and Windsor, Ont., Canada. (See Fig. 8).

Fig. 2—A Reconstruction of a New Installation of Trolley Buses in Shanghai

In an article entitled The Prospective Fields For the Rail Car, Trolley Bus and Gasoline Bus in City Transportation,' this subject has been treated in great detail by J. C. Thirlwall of the railway and traction-engineering division of the General Electric Co. Extracts from this article are given in Appendix 2.

The six-part article entitled The Place of the Motor-bus in Passenger Transportation,' by Walter Jackson, is well worthy of the attention of automotive engineers. Some extracts from it are given in Appendix 3.

In this trolley-bus form of machine the vehicle is released immediately from the handicap of running on tracks, and while it is, so to speak, tied to the trolley wire, the flexibility of movement has many real advantages. It is free to pass roadway obstacles and can pick up and discharge its passengers at the sidewalk. Incidentally, its operation may relieve the railway organization from street-paving obligations, and there should be a decided further economic advantage in a lower cost of mechanical upkeep because the vehicle operates on rubber tires.

FIG. 6—VEHICLES OF THE REGULAR STREET-CAR TYPE HAVING A SINGLE POLE WITH A FORK FOR MAKING CONNECTION WITH THE TROLLEY WIRE ARE IN SERVICE AT MINNEAPOLIS

Its employment requires practically no changes in the organization for operation and maintenance and, with the use of central-station energy, it should be able to compete with buses operated by gasoline costing a much higher and varying price for the power required in transportation, as well as a lower upkeep cost by the use of electrical equipment for frequent speed-changes as compared with mechanical transmissions. Another important consideration in this direction is the possibility that, within a short time, taxation of the use of gasoline on a gallonage basis which exists at present in a number of States may become a general practice throughout the Country, which would prove a serious handicap to a public-service organization continuously operating large numbers of machines.

DUAL-POWER BUS-EQUIPMENT

The next logical step in the development of more flexible vehicle equipment would be the inclusion in the trolley bus of a secondary source of power for supplemental operation. This may be either a gas-engine equipment or an electrical auxiliary in the form of a storage-battery chargeable either from the line or at the power station. The obvious advantage of either of these is that supplemental vehicle-service could be rendered beyond the limitations of the trolley, and in this way there would be a marked increased earning capacity in a machine so equipped. From an investment standpoint, in going into new territories, such a dual power-equipment would require only a partial installation of overhead line-construction, permitting the vehicle to be operated beyond these extensions in various directions until the earnings from such extended service would warrant the additional investment in further line installation. Another place for the use of such a vehicle would be in those instances where short non-paying trolley-lines already have been abandoned and which have paying territories adjacent to them either laterally or beyond their zones. In other words, the resuscitation of such lines by this means would provide for return parallel routes in better paying localities or an extension of the service beyond the point where the existing lines end. Therefore, whether the auxiliary source of power should consist of gasoline or electrical equipment would depend upon the extent of off-line service to be rendered, particularly considered over long-time periods or years of operation. For instance, if operation from the trolley line was 75 per cent of the bus route and the auxiliary service 25 per cent of the route, gasoline equipment would be indicated. If the off-line service represented 50 per cent of the performance it would become desirable to use central-station power and, for this purpose, an electrical equipment would be indicated. It is well to accentuate here that such electrical equipment in the form of storage-batteries, if charged intermittently from the line, would not require to be very large, because the intermittent off-line service is not likely to be at any time more than a mile or two of operation and a comparatively small battery would serve this purpose. The employment of such a battery equipment with a means for intermittent line-charging would have to be weighed from an economic standpoint with the contrasting factors of the use of cheap central-station power against the use of gasoline.

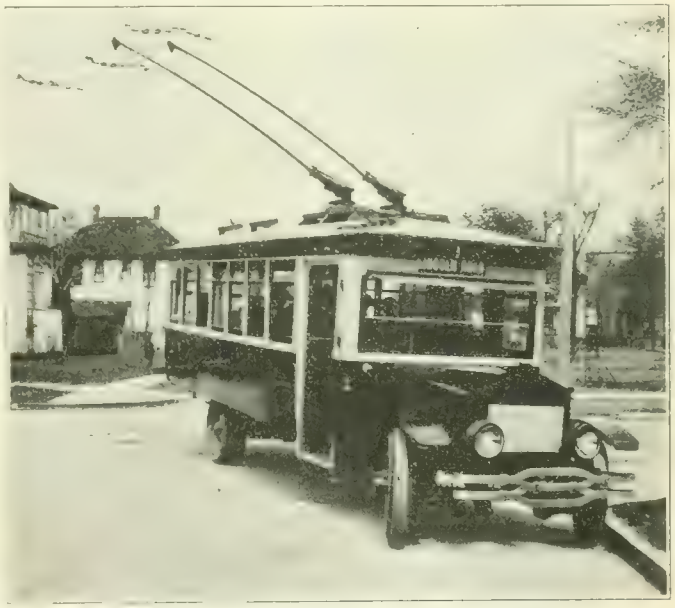


FIG. 8—TROLLEY BUS IN SERVICE AT WINDSOR, CANADA

FIG. 7—TYPE OF TROLLEY BUS THAT IS IN OPERATION AT TORONTO. THIS VEHICLE FOLLOWS THE CONVENTIONAL BUS CONSTRUCTION AND HAS THE CONTROL MECHANISM UNDER THE HOOD

In applying such trolley or dual-power buses to existing lines where trackage and a single overhead trolley is or has been in use, avoidance of installing the second overhead wire might be effected by the use of rail-contact devices incorporated in the vehicle. The advantages and disadvantages of such compromise equipment would have to be weighed in each case, but trolley-bus operation with a rail-contact device is well within the range of feasibility. A still further factor in the general situation is that the more broad the use of such trolley buses be-

the longer the vehicles would be. Naturally, with a limited output of these, the price at the moment is higher than it would be when numbers of them were manufactured.

Independent Buses With Electric Transmission

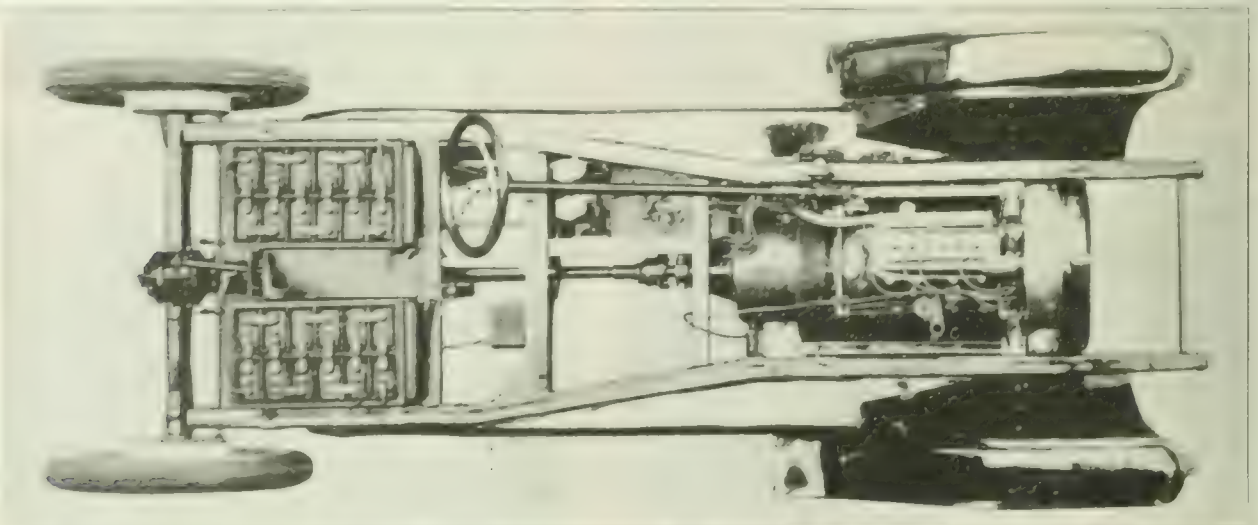
Aside from the trolley-bus type of vehicle utilizing central-station power, it may be well from the standpoint of lower transportation cost to consider the employment of vehicles for ordinary bus service having gasoline-electric transmission-systems in contrast with the straight gasoline bus with mechanical transmissions.

The Tilling-Stevens gasoline electric system, as developed in Great Britain, has been in use there since 1908; and, at present, at least a dozen transportation companies employ fleets of from 20 to 300 motorbuses of this type, and very many more vehicles using this system are employed as motor trucks. This system is particularly simple, consisting of a gasoline engine having directly connected to it an electric generator. A separate electric motor is used to drive the propeller-shaft. The control consists of a forward, neutral and reverse controller, and the speed is regulated by the engine throttle in combination with a lever varying the field resistance of the generator and the motor.

In passenger-transportation service the smooth operation, the even acceleration and silence contribute to its popularity, and its economy of operation is enhanced by these very same factors at the same time. For example, when the vehicle has been accelerated to its normal speed, the power required to maintain this speed is a small percentage of that required for acceleration. Therefore the engine can be slowed down almost to idling speed; but the motor speed and, consequently, the car speed, is maintained by reason of the change in the regulation of the motor and the generator fields. Well substantiated claims are made that both fuel-consumption and maintenance costs are very low in these vehicles.

In the United States, gasoline-electric transmission-systems have been used in various forms from time to time for many different purposes in the freight and passenger-transportation fields and for military-equipment requirements. In motorbus service, the Fifth Avenue Coach Co. used a group of 10 buses (See Fig. 9) from 1908 to 1914 in regular schedule operation, and some of them remained in emergency service until 1917. These were designed by H. S. Baldwin, an automotive engineer, and built under his supervision by the General Electric Co. The electric-transmission system employed in these vehicles was entirely satisfactory from an operation standpoint, although they were somewhat handicapped by being used with gas engines that were not entirely suitable. This type of transmission equipment would have been continued except for the fact that it was not in regular production and, therefore, could not compete with the mechanical-transmission equipment that was more readily available in the market.

Prior to the use of this group of machines, an experimental vehicle designed by Mr. Baldwin was put into operation in 1905. This is interesting from the fact that the engine was started electrically, using the generator as a motor, and was, therefore, probably the first vehicle to embody this self-starting feature. Incidentally, it had a semaphore signal at the back which was thrown into a horizontal position by the torque of the motor when the vehicle started, and which was returned to a vertical position by a recoil spring when the vehicle stopped. A high-speed electrically operated fan was used also to cool the radiator coils, which provided high ventilation with the vehicle running at low speeds. The equipment of these buses is described in articles by H. S. Baldwin



entitled Gaso-Electric Motorbuses on Fifth Avenue, New York City[6]; and Some Special Applications of Gasoline-Electric and Storage-Battery Automobile-Equipments.[7] A later example of a gasoline-electric system is illustrated in Fig. 10.

Bus service is distinctly different from any other of the several forms of motor-vehicle operation with which we are familiar, inasmuch as the machine is repeatedly operating over a fixed route where the road-surface conditions are constant except for varying weather conditions and periodic seasonal changes. The other operating conditions, such as the mileage, the speed and the number of stops per mile, as well as the average load carried, are almost equally fixed and constant; so, with all these operating factors known in advance, it is comparatively easy to determine the relative advantages of one particular equipment as against another.

In bus operation, the cost of constantly recurring speed changes is an important factor, not only with reference to the upkeep of the transmission, but also the dynamic influence of these stops and starts upon the wear and tear of the other parts of the vehicle such as tires, brakes and the like, with particular emphasis on the fuel consumption; and it is in reference to these considerations that the use of electric transmissions may be of very much greater importance in this field of service than they have been hitherto in the use of motor-vehicle equipment. Electric-transmission systems have been in use successfully for long periods in bus operation; whereas, for regular merchandise haulage, there has not been equal progress with such equipment. The reason for this lack of progress will be obvious to anyone studying the situation, which is governed largely by the influence of competing apparatus made in quantity and much more familiar to the average user.

Just prior to the war, a committee of the Metropolitan Section of the Society, including myself, made an extensive research into what had been done in this field throughout the world. A report is on record that indicates the findings of this committee in brief, as the subject was so broad as to render a more complete report impracticable at that time. It is well known that many systems of electric transmission have been devised and applied, but their use has not become general for the reason that quantity production was never attained in any case. Consequently, it was difficult to compete with products being made and used on a mass-production basis combined with a natural tendency on the part of the common user to employ what exists in ordinary practice instead of utilizing new departures, notwithstanding whatever the economic advantages might be.

With the coming of a very general application of automotive equipment to public passenger-transportation, particularly in the hands of existing railway organizations, the reason for the existence and the employment of electric-transmission equipments is changed materially, and the serviceability of these, based upon their value in reducing the cost of operation and upkeep, is likely to bring these systems into active use. As a matter of fact, all of the parts required for such equipment exist as standard units having other applications, and the almost universal employment of electric starting-sytems in automobile equipment has dissipated much of the mystery and the ignorance that previously prevailed and constituted a serious handicap to the use of electrical

[6] See *General Electric Review*, November, 1908, p. 214; see also *Street Railway Journal*, Dec. 2, 1905, p. 986.

[7] See *General Electric Review*, March, 1912, p. 127.

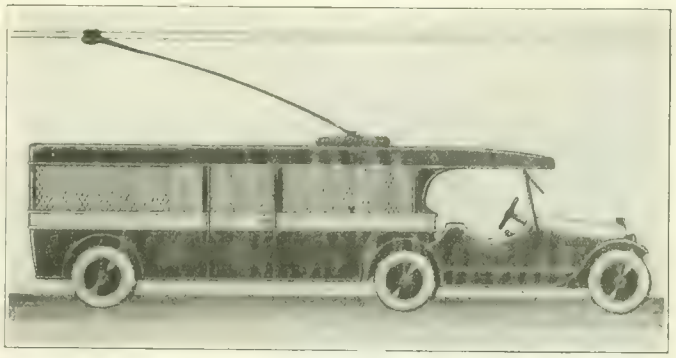


FIG. 11—A TYPE OF VEHICLE WITH A TROLLEY POLE ON THE TRAILER THAT IS SUITABLE FOR THE TRANSPORTATION OF PARCEL POST OR EXPRESS MATTER

equipment for any purpose where its use could be avoided.

The electric street-railway organizations, being in effect electric-transportation engineering-institutions, should be more inclined to prefer electrical equipment than mechanical; and it is logical, consequently, to forecast that the obstacles which have existed heretofore to impede the application of economical electrical-transmission systems are likely to disappear. It would, therefore, be well for automotive engineers to refresh their knowledge of the various systems that have been in isolated use for various purposes, so that any superior operating value that they may have will be available to the operating advantage of electric street-railway organizations using motor-vehicle equipment. One important phase of the case should be emphasized in the following consideration, that in electric-transportation organizations competent care and maintenance for the particular features of these equipments is available more readily than anywhere else. Another is that all of the electrical equipment necessary is available from the same large manufacturing organizations that have been the sources upon which railways have depended for their equipment requirements in the past. As in the case of the trolley bus, this specific type of machine is not recommended as a "cure-all" to meet every requirement, but its importance is now accentuated more than ever before.

BODY AND CHASSIS REQUIREMENTS

Body and chassis requirements peculiar to mass transportation constitute a subject that, from the standpoint of the designer and the manufacturer, has not yet received much consideration; at least, it has been sidetracked by the necessity of making use of material and equipment designed for other purposes, but constituting the only kind immediately available for application to

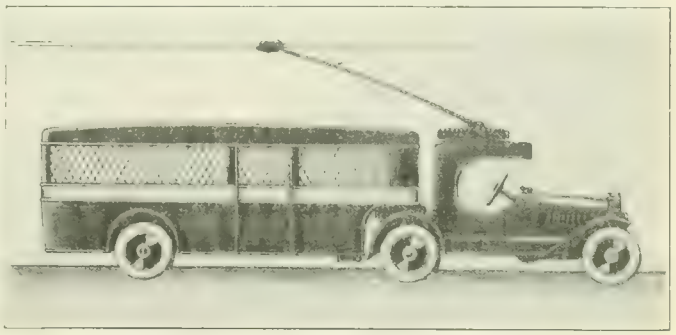


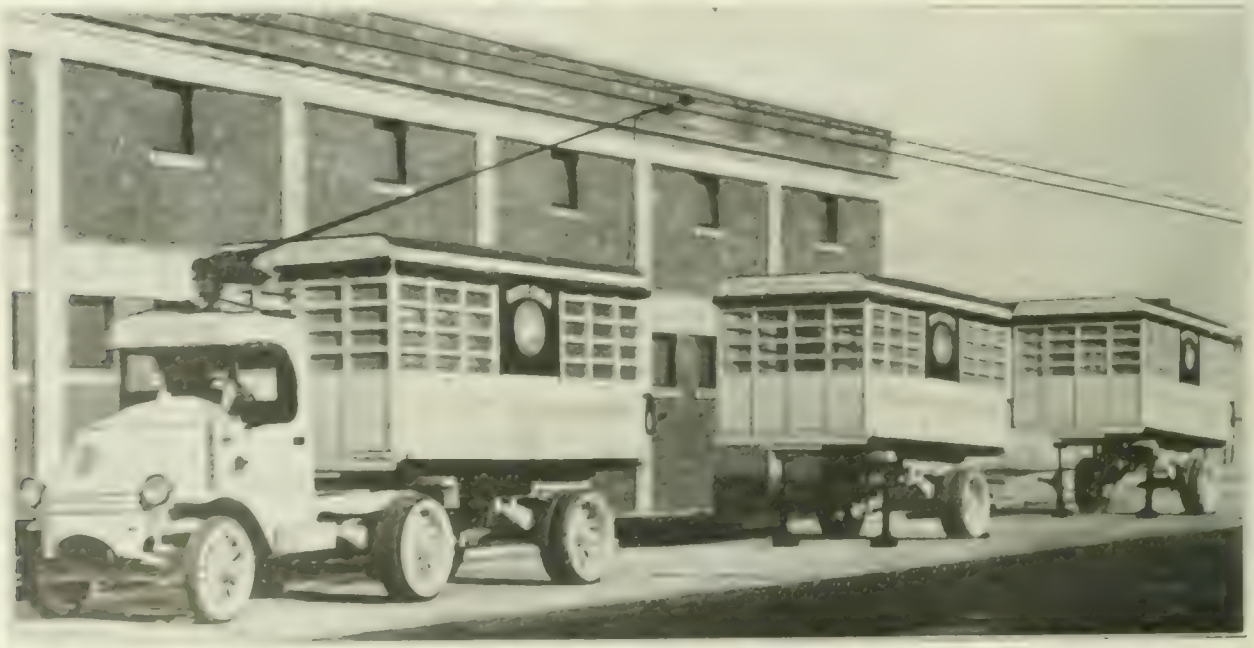
FIG. 12—ANOTHER POSSIBLE TRACTOR AND TRAILER ARRANGEMENT WITH THE TROLLEY POLE ON THE TRACTOR

[illegible] Manufacturers dependent upon [illegible] as their main source of revenue are not deflected easily into a new channel where the product is unknown, the demand intermittent and the [illegible] operating requirements necessitate many changes from their standardized products. Naturally, [illegible] has been furnished with hesitancy and loaded down with handicaps. Some [illegible] manufacturers have made changes in their equipment as far as might reasonably be expected, with the purpose of encouraging development in this "new-business" line; but, on the other hand, many manufacturers have refused to depart from their standard products, leaving the responsibility of any misapplication made resting upon their agents. The agent, on the other hand, being forced to maintain his existence under the trying business conditions that have prevailed in recent years, particularly in the motor-truck field, has, in many cases, been desperate to make use of any business opportunity presented, and, "none being so liberal as the desperate," [illegible] have succumbed with the local blacksmith and the local wagonmaker, not forgetting the finishing touches of the painter and the decorator, in attempts to produce [illegible] vehicles built upon truck chassis. In most [illegible] these necessities have been heinous violations of the engineer's art, as we know it from an engineering standpoint and, in a few years from now when a rational advance has been made in proper design, these machines will be held up to us as horrible examples of our earlier ignorance and incompetence.

Is it any wonder, then, that we find the conservatively trained executives in public passenger-transportation fields in such an attitude of reluctance to adopt this misfit equipment that violates, from every point of consideration, the tradition of their industry as developed by years of experience? We should acknowledge immediately the radical difference existing between their experience and ours as automotive engineers. We are principally concerned with the design, the construction and the application of isolated unit vehicles where, in the passenger-car direction, speed, luxury and comfort are an ultimate attainment; and, in the commercial direction, the standardized production of merchandise vehicles that would operate with tolerable satisfaction under a great variety of service conditions. The street-railway engineer and the executive, on the other hand, have been required to provide the continuous performance of a rigidly standardized transportation under conditions where failure and interruption are not tolerated, where the good will of large communities of patrons must be catered to and often complied with under trying conditions, and where "safety first" has even been more vital than continuity of operation.

[illegible] Showing a Semi-Trailer and Two Trailers Might Be Handled by a Tractor

The Tractor Must Be Used Away from the Line to Collect the Trailers and Would Then Come to the Line as Shown to Be Connected with Contact-Shoe Power for the Large Portion of the Run



[illegible] Semi-Trailer Motor Vehicle for Trucks and the Motor-Bus Which Forms One of Both the Trailer

Public-Service-Transportation Permanency

Solidity and permanency of organization have been absolutely necessary, and many obligations of a municipal, political and regulatory nature, have had to be complied with as requirements to legal or actual existence. Therefore, we should feel pretty sure that any general assumption that the apparent temporary success of independent operators forebodes displacement of the more permanent railway-organization service is entirely delusive and that, within the lapse of a short period, these organizations will seriously determine upon a rational program for graduated advance in directions of the newly demanded service.

The problem of developing satisfactory equipment is not solved readily; it demands a serious study on the part of both the railway and the automotive engineer. The nature of the undertaking should impress us with its importance, and definite steps are warranted in recognition of the enormous progressive possibilities opened up to both the automotive and the railway industries in meeting new expansion in directions that have not been contemplated previously by either of these industries.

Prospective Street-Railway Business

It requires no stretch of the imagination to realize what may be accomplished if these well founded and experienced transportation organizations, by the collaborating influence of the automobile industry and the consequent employment of flexible vehicles, should be suddenly released from the rail and wire restrictions that have limited their operations definitely to almost a single field of service. With flexible vehicles operated to a large extent under the advantages of central-station power and distribution, new fields of business development are opened immediately. Their city passenger-transportation can be augmented materially with very much less investment requirement than similar expansions called for previously. Sightseeing transportation is legitimately within their business province and summer touring-service is a prospective possibility; but, more important than these, is the opportunity to handle the local transportation of merchandise, parcel post and express, as well as local freight-transfer for merchants and manufacturers, and the possibility of collaborating with the steam railroads in putting into execution the recently much talked of store-door delivery. Such operations may require changes in the limitations of their existing franchises, but these changes or enlargements should be secured readily in view of the advantages rendered to their communities by the increased transportation facilities afforded. Their ability to supply a highly organized, economic and varied line of service to the business interests in their immediate vicinities should certainly fortify them in demanding the rights necessary to conduct these progressive and improved operations. Examples of equipment that might be used for such transportation are shown in Figs. 11 to 15.

Heretofore, the transportation of freight by street-railway equipment has not been very general in this Country; nevertheless, the possibilities for business in this direction are so extensive as to warrant the energetic action required to bring it into common practice. Necessity, "the mother of invention," in developing the ways and means to accomplish this may have been lacking in the past; but, in the light of necessities that have existed in Europe, we have some good examples of what can be done under pressure. In Appendix 4 is an extract

[8] See *Electric Railway Journal*, May 22, 1920, p. 1062.

Fig. 16—A French Six-Wheel Gasoline Bus in Which Both the Front and the Rear Wheels Perform Steering Functions

from an article entitled Teuton Trolleys Handle Freight[8]. Briefly this shows that in Germany, as long ago as 1903, there were 60 of the 148 street railways then in use that were handling freight. In 1913, there were 60 of the Prussian street railways and 19 of the railways in other German states that were handling freight, with 2600 cars for package mail and freight, of which 964 were regular freight cars of 6-metric-ton (6.61 net tons) capacity each. In Vienna, Austria, up to 1918, local street-railways had made 110,000 car-trips, the equivalent of 310,000 wagon-trips. For the same amount of work, 350 horse trucks or 100 motor trucks would have been needed.

Therefore, the attitude of our street railway organizations, instead of being that of resistance and reluctance toward the use of automotive equipment, should be a complete and energetic change to a realization of the enormous new business fields open to them to invigorate their organizations and to reestablish a happier financial condition by seizing upon this basis of a new start with added fields for progressive development.

Flexible-Equipment Requirements

Having indicated the several directions of possible expansion, we can return again to the body and the chassis equipment necessary to meet these several new requirements. In seeking a solution of this new-equipment problem, we must presuppose a favorable attitude toward new methods to be adopted, necessarily requiring

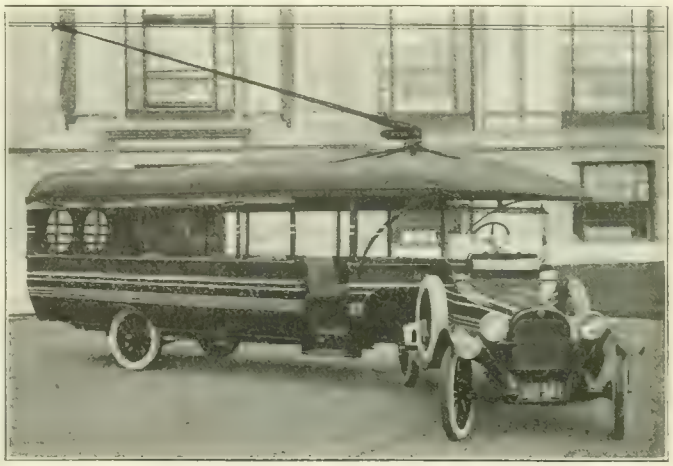


Fig. 17—A Car with a Semi-Trailer That Seats 29 Passengers and Gives a Low, Wide Comfortable Passenger Car Making a Turn in a Comparatively Small Space

[illegible] the performance required, and to safeguard the investments to be made for such [illegible]. Demand principally exists for large [illegible] with low operating cost and one-man [illegible].

Other features sought are a low center of gravity, a [illegible], large seats, wide aisles, compensating spring-[illegible] and accessibility for maintenance and repair. In operation, there is need for smooth acceleration, ample [illegible], adequate brakes and permanency of the power-[illegible] under continuous operation. Desirable additions to equipment features are a detachability of powerplant [illegible] and normal body changes. Fundamental necessities are [illegible] of parts and standardization of the units employed. These requirements cannot be supplied readily in machines designed primarily as trucks. Their special service requirements demand correspondingly special designs.

Motor omnibuses in European cities are good examples of specialized development. These are not, however, generally recognized as offering a broad solution for American transportation requirements. They are particularly applicable in congested metropolitan zones but, under average American city conditions, something less cumbersome is desirable. To provide for large passenger capacity, longer vehicles of the single-deck type, similar to that shown in Fig. 16, are in demand. This calls for increased distribution of axle carrying-capacity. Some special developments have been provided having double rear axles; some others have provided two rear and two front axles.

A combination tractor-and-trailer design, such as that illustrated in Fig. 17, is not entirely new in passenger transportation, and it certainly has many advantages worth considering. This type of design will provide the following features:

(1) Three axles for load distribution of the passengers and the powerplant

(2) Three sets of springs for flexible suspension

(3) Steering on all six wheels, resulting in a short turning radius

(4) Braking power application to two axles as well as to the drive-shaft

(5) Powerplant equipment confined to the tractor part, and consequent freedom from power-equipment apparatus in the trailer passenger-section

These features allow a wide, low-hung body, comfortably accommodating both seated and standing passengers. Pneumatic tire equipment of normal size is made serviceable, thus reducing the unsprung wheel weights and the operating cost. The tractor can be detached from the trailer section for ease of repair and maintenance. Trailer bodies of open and closed types can be interchanged. In case of accidental damage, only part of the equipment is put out of service; and a carrying capacity up to 100 passengers can be provided for within reasonable length of vehicles. Illustrations of various types of vehicle are shown in Figs. 18 and 19.

[illegible] such a brief summary of this particular design, it will be seen readily that, in meeting the demands for larger passenger capacity than is supplied usually by the normal four-wheel vehicle, there is an opportunity to extend the body space and distribute its weight on a rational basis. Extending the length of vehicles usually sacrifices their turning ability; but, with three axles disposed along the length of the vehicle and all of them performing steering functions, controlled or governed in a specific manner, any reasonable turning radius required for city operation can be attained. The consequence of all these features is that an approach is made to meet the demand that the street-railway executive asserts exists in the necessity for handling a large number of people comfortably and flexibly with one-man control.

This type of vehicle, having included in its power operating-equipment the combinations necessary to utilize central-station power or to operate independently, is a step in the direction of the least departure from the existing practice in street-railway organizations. It provides for the utilization of the cheap power that they are equipped to furnish and tends fundamentally toward the preservation of their existing property and investment with a marked extension in the radius of application of the transportation service in new and profitable directions.

A somewhat similar application of tractor-and-trailer equipment for freight haulage and package transfer would similarly extend the earning power of these corporations to a marked degree. It is easy to realize that, with the cooperative agreements necessary, a tractor of the railway company having dual power-equipment could transport the loaded trailers of merchants and manufacturers between various points within the operating zone with the utilization of central-station energy for a large part of the performance. Where permanent cooperating relationships could be established by the street railways and the steam railroads for the conduct of store-door delivery between the railroads and their customers, flexible operating equipment and adequate line facilities would be justified. Even if the latter involved a considerable investment in permanent overhead structures within the zones of greatest traffic, such transportation would bring to the railway organizations substantial and permanent revenue for operations well within their scope and entirely justified by reciprocal economic advantages. Fig. 20 gives an example of the extent to which the tractor and the trailer are coming into use by large transportation companies.

With problems such as these existing in directions that have not heretofore existed for either the street-railway or the automotive industry, and including both business and engineering opportunities, there should arise immediately a progressive energetic response in joint cooperation to meet the purposes of both parties. The field for expansive activity is enormous and the automotive industry should immediately recognize that in the street-railway organizations, taken collectively, there exists a greater potential group-consumer for its products than has ever existed in any single direction. In other words, here we find what can be regarded practically as a unit group of customers experienced as no others have been in the utilization of transportation equipment, with requirements that are uniform in character and with executives and engineers particularly qualified to coordinate with the engineers and executives of the automotive industry.

APPENDIX 1

In a report to the New England Street Railway Club Committee made Feb. 2, 1922, the committee calls attention in a general way to features that should be taken care of in the construction of a bus, without discussing the proper type of gasoline engine for the bus. Briefly, these are

(1) Reliability and ability to render uninterrupted service 18 hr. daily

(2) A high degree of riding comfort, not obtainable

by a common motor-truck chassis with a body hung on it. There should be (*a*) proper spring suspensions, (*b*) as little rear-end overhang as possible and (*c*) a low center of gravity. The bus must be more comfortable to ride in than a street car, if possible

(3) That tire and wheel equipment be fitted to the roadway

(4) An absolute reliability of brakes

(5) Not more than two 15-in. steps for ingress and egress

(6) An attractive body appearance from the inside and the outside

(7) A rapid pick-up and rapid braking speed

(8) A low gasoline consumption

(9) Good ventilation and light

(10) A seating capacity of 21, 25 or 29 passengers

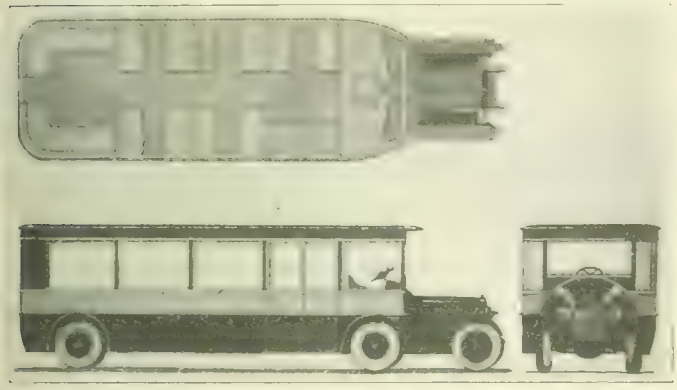


FIG. 18—ANOTHER TRACTOR AND SEMI-TRAILER COMBINATION ACCOMMODATING 30 SEATED AND 20 STANDING PASSENGERS

In This Arrangement the Tractor Has a Short Wheelbase and Is Intended To Have Either a Trolley Pole or a Gasoline Engine and a Transmission, There Being No Power in the Trailer. The Tractor Is Detachable from the Trailer for Ready Servicing or the Substituting of Other Vehicles in Case of Damage to Either Member of the Combination. The Steering Is Performed by All of the Axles and the Steering Functions of the Rear Wheels Are Controlled by the Angular Movement of the Tractor

In its discussion on the trackless trolley, the committee gives the history of its development which, the report says, started in Berlin, Germany, with a line constructed by Siemens & Halske Actien Gesellschaft. Most of the developments have been abroad, in Germany, Italy, France, Great Britain, Shanghai, China, and Rio de Janeiro, the last being a storage-battery line, and there being one line built at Los Angeles, in 1910. Only recently have there been any serious attempts to develop the trolley bus in this Country.

In the whole world, the committee points out that, the development of this vehicle has extended to not more than 200 miles of line operating under widely different conditions. The committee also points out, however, that experience with these few lines should be valuable because, if conditions have changed so as to make this method commercially feasible, the experience with designs and types should enable present-day users to avoid mistakes of the past. The committee then states

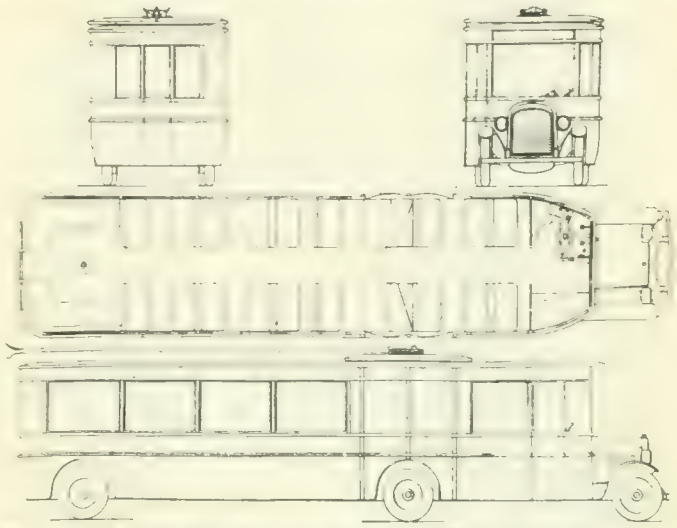


FIG. 19—ANOTHER ILLUSTRATION OF THE POSSIBILITIES OF THE TRACTOR AND TRAILER ARRANGEMENT

This Vehicle Will Seat 50 Passengers and Has Space Enough To Accommodate 40 or 50 More Comfortably. It Is Intended for Operation from the Trolley Line or by a Gasoline Engine and Has Both an Electric Motor and a Gasoline Engine and a Transmission, thus Necessitating a Long Wheelbase for the Tractor. One Man Operates the Vehicle and Has Both a Controller for Electrical Operation and a Gasoline-Engine Control. The Brakes in Both of These Vehicles Are on the Driving Wheels and on the Rear Steering-Wheels. As a Fifth Wheel Connection Is Provided over the Center Driving Axle, the Steering Functions Are Performed by All of the Axles and It Is Possible To Turn the Vehicle Which Is 36 Ft. Long in a 30-Ft. Radius

Assuming that there is a field for the trackless-trolley bus, it seems to the committee that in developing a suitable vehicle the following desirable features should be incorporated

(1) Two or four-wheel drive and two or four-wheel braking, depending on the weight of the vehicle

(2) Power applied as directly as possible to the wheels

(3) Series-multiple control

(4) Some storage-battery capacity, floating on the line to give greater flexibility in case of blockades and the like

(5) An adjustable device for grounding the

FIG. 20—AN EXAMPLE OF THE EXTENT TO WHICH THE TRACTOR AND THE TRAILER ARE COMING INTO USE FOR PACKAGE AND FREIGHT TRANSPORTATION

(2) Elimination of all unnecessary mechanical parts such as the transmission, the differential and the live axle, secondary simplicity and ruggedness in machinery with ease of inspection and maintenance

(3) Solid or pneumatic tires with rubber or equivalent shock absorbers between the chassis and the body

(5) A low center of gravity and a minimum distance from the ground to the floor of the bus, not to exceed 30 in.

(6) Improved current collectors designed so as to prevent any loosing of current under all weather conditions and to prevent the collector from passing the wires at operating speed

(10) Body designs to conform to best modern practice

(11) Minimum weight consistent with these features with a seating capacity of about 21 to 25 passengers

The committee concludes that there are no really reliable data as to the cost of operation of trolley buses in America now, and therefore gives some of the costs experienced at Leeds and Teesside in England. Therefrom, it makes some suggestions of its own as to the cost of trolley-bus operation, on the assumptions stated in table 1.

TABLE 1.—ASSUMPTIONS OF THE NEW ENGLAND STREET-RAILWAY CLUB COMMITTEE.

Scheduled Speed, m.p.h.	10
Time Buses Operate, per day, hr.	18
Bus Capacity	25
Buses Necessary to Buses in Operation	2
Cost of Trolley Line per mile	$6,000
Cost of Each Bus	$7,500
Life of Bus, years	10
Cost of Power, cents per kw-hr.	2
Power Consumption per Bus-Mile, kw-hr.	1.5
Cost per Set of Solid Rubber Tires	$200
Life of a Set of Solid-Rubber Tires, miles	10,000
Overhead-Line Maintenance and Depreciation, per cent	10
Equipment Maintenance, per Bus-Mile, Assumed the Same as Car Equipment, cents	5
Hourly Wages of Operators, cents	63

When this is computed for a year at a total mileage of 65,700 miles and a total cost of $16,800.45, the total operating cost per bus mile is 25.51 cents. This, of course, does not allow for dead mileage or for the use or the maintenance of the highways. The last item, even though treated by the community through taxation, should nevertheless be added to the operating cost in any comparison.

The committee lists the following desirable and undesirable features of the trolley bus

Desirable Features.—The chief desirable feature of the trackless trolley is that it makes possible the extension of lines to furnish transportation facilities to newly developed communities, where the traffic must of necessity be light for a considerable period, at a small initial expenditure. This admits of the possibility of changing to car operation later without the loss of any appreciable amount of the capital thus invested.

The second desirable feature is that this type of vehicle is very similar to operation by street-railway companies because its general characteristics are the same as those of the trolley car, making it possible to operate it with the same transportation and maintenance organization as that of the usual street car. Another desirable feature is its flexibility, which, of course, is greater than that of any type of electric car, and the last is curb loading and unloading.

Undesirable Features.—These include lower operating speeds, lower carrying capacity than that of a street car, possible difficulties with the current collector and overhead construction and operation upon the highway, the maintenance of which is not under the control of the transportation company.

In conclusion, the committee recommends that New England street-railway men keep constantly in mind the possibility of adopting any one of these methods of operation in the development of their service. It then says

> The committee hesitates to recommend in a report of this sort just where any individual street-railway operator should adopt these different methods of transportation, but feels that street-railway men as a whole ought to be quick to recognize the possibilities of these new methods and are in duty bound to adopt them in carrying on the natural monopoly that they have for street transportation of passengers in the various districts they serve, wherever careful analysis of the situation shows that as good or better transportation could thus be provided at less cost than by the present methods.
>
> In the matter of one-man operation, the committee is of the opinion that it has been demonstrated that a properly equipped electric car can be operated by one man under many different operating conditions with advantage to the public and the street railway. Further, this method of operation has the endorsement of our public authorities and should direct our attention to operation of cars with one man wherever careful analysis shows that this can be done to the benefit of the service, all things considered. In addition, the recent development on certain properties of the so-called light-weight double-truck car, whether operated by one man or two, should be studied closely, as the committee believes that there is a considerable field for this type of car, particularly for one-man operation.
>
> Relative to the motorbus and the trackless trolley, considerable advancement has been made during the past year and the builders of each now have in mind to a large extent the needs of the street railways. There are certain portions of street-railway lines now existing where, on account of the expense involved, it undoubtedly is impracticable to rebuild the tracks and where it might be preferable either to abandon or tear up the tracks and, by the addition of another overhead wire, install the trackless trolley. The committee believes that in many instances it would be preferable before even going to the expense of installing the trackless trolley to install a motorbus service over the line on which the tracks have been selected for abandonment, and to try out the motorbus for a period before undertaking the expense of equipment for the trackless trolley.
>
> The committee feels that the street-railway operators should keep these two vehicles constantly in mind when contemplating extensions of lines either within or without the territory now served by them. In the early days of operation on these extensions, we suggest to the operating officials the advisability of using the motorbus until the final route has been established and a sufficient amount of traffic has been created to warrant the expenditure for the equipment of the trackless-trolley line. In the establishment of extensions to the street-railway lines during the development period, there seem to be three different stages that the street-railway operator should contemplate with the three vehicles that have been studied by this committee.

(1) A motorbus service tried out over various routes to establish definitely the route by which it will best serve the public at the least expense

(2) The trackless-trolley service placed in effect after the route has been established and a sufficient number of riders obtained

(3) The laying of tracks and car operation as the community becomes built-up and the receipts warrant the capital expenditure

Once the tracks are laid, the question of one or two-man operation should be carefully figured to determine which will be the more economical and satisfactory, all things considered.

The committee desires to give due credit to the following organizations and publications for information that we have obtained in compiling this report: *Electric Railway Journal;* American Electric Railway Association; *Public Service Aera;* and the annual reports of the Public Service Commission of Massachusetts.

APPENDIX 2

The writer of the article quoted below,[9] J. C. Thirlwall, has tabulated the respective costs on a comparative basis for a variety of conditions. In general, the calculations indicate that

(1) Where rush-hour headways of 3 min. or less are required with safety cars, rail cars are the most economical and, up to 6-min. headways, offer successful competition to the other types where the road is a going concern

(2) On longer headways, the trolley bus appears to have the advantage due to the lower fixed charges

(3) The gasoline bus, on account of higher operating cost, does not offer competition to the rail car until minimum headways of 10 min. are reached on new routes and 20 min. on existing lines

(4) The trolley bus is more economical than the gasoline bus up to headways of 60 min. or longer

(5) The minimum headways in the respective fields are as follows: rail cars, 3 min. or less; rail cars or trolley bus, 3 to 6 min.; trolley bus, 6 to 60 min.; and gasoline bus, 60 min. or more

The tabulations show that the difference in favor of the trolley bus as compared to the rail car operating on headways of 7½ or 10 min. on an existing route is too small to warrant even the suggestion that rails and equipment should be scrapped and replaced with the new form of transportation. It is not until minimum headways of 15 or 20 min. are reached that the estimated saving of the trolley bus over an existing rail route becomes sufficient to justify such a suggestion.

To illustrate these conclusions and to show the premises on which they are based, a number of tables are presented in which a direct comparison is made of the elements of investment cost for a rail system and for the two types of bus. The actual cost of laying rail in paved streets, of erecting overhead-trolley lines, or of building power stations, sub-stations or shops, varies considerably as between different localities, but the unit costs used in the tabulations are believed to represent fair averages for present construction.

For instance, a figure of $60,000 per mile has been taken for single track with few turnouts laid in a paved street; $75,000 for single track with more turnouts for shorter headways; $100,000 as about the lowest estimate for a route-mile of light double-track for safety cars; and $120,000 for a route-mile of heavy track for double-truck cars. In some localities tracks may be laid for less than these figures. In most large cities they would be considerably exceeded; but they are believed to indicate with a fair degree of accuracy the magnitude of the biggest item of investment that can be saved by the use of the rubber-tired vehicle.

[9] See *General Electric Review*, December, 1921, p. 974.

TABLE 2—AVERAGE CONSTRUCTION COSTS

Single Track, per route-mile	$60,000 to $75,000
Double Track, per route-mile	100,000 to 120,000
Trolley Lines, per route-mile	5,000 to 6,500
Transmission Lines, per route-mile	1,800
Generating Station, per Kilowatt of Maximum Output	125
Substation, per Kilowatt of Maximum Output	40 to 50
Shops per Car Used	1,500 to 2,500
Safety Cars	6,300
Double-Truck Cars	12,000
Trolley Buses	8,000
Gasoline Buses	8,000

Overhead-trolley lines using wooden poles with cross spans can be erected for about $5,000 per mile where only one trolley wire and no feeders are required, and for double track with ordinary feeders should not exceed $6,000 per route-mile. The two-wire trolley required for trolley buses costs about $500 per mile more than the ordinary type of construction and $1,000 more per mile when the line is run on both sides of the street. The transmission line is estimated at $3,500 per mile, and it is assumed that the length of the transmission system is one-half that of the distribution lines. A summary of these and other unit-cost figures is shown in Table 2.

The rail car requires an investment in each of the items; the trolley bus dispenses with the track, but necessitates the use of all the other details; the gasoline bus requires an investment in the vehicles themselves, and in storage and shop facilities, but eliminates the remaining construction charges.

On fairly long headways, that is, from 8 to 20 min., the fixed charges on the rail route will exceed the operating costs, and even on a heavy-traffic route, they will amount to 40 per cent of the total cost of operating the line. The handicap of these heavy investment charges has given the gasoline bus its opportunity and enabled the jitneys to compete successfully in many instances with the established traction lines. The gasoline bus has a higher power-bill and a higher maintenance cost than the safety car, and the depreciation of its driving equipment is decidedly more rapid than that of electric motors and control on the rail cars; but, even so, for many conditions of traffic it is the more economical of the two methods of transportation. However, its proponents have frequently tried to force it into classes of service where its higher operating costs

TABLE 3—OPERATING COST IN CENTS PER CAR-MILE

Items	52-Passenger 36,000-Lb. Rail Car	32-Passenger 16,000-Lb. Safety Car	30-Passenger 10,000-Lb. Trolley Bus	30-Passenger 10,000-Lb. Gasoline Bus
Maintenance of Way and Structure	3.0	2.0	0.7	0.0
Maintenance of Equipment	3.4	1.7	4.0	8.5
Power	5.9	2.5	2.3	7.0
All Other Expense	19.0	12.0	12.0	12.0
Total Operating Expense	31.3	18.2	19.0	27.5

cents for the main-
id tires, 1.5 cents for the body and the
for the engine and the transmis-

bus would presumably have the same cost
, body and truck upkeep, but only 0.5 cents
the motor and the control, making its total main-
per mile or 4.5 cents less than that
e vehicle.

power account, due to higher friction, the
bus will take more power per ton-mile than
car, but its lighter weight will somewhat more
than offset this and make its total power-cost a trifle
than that of a safety car. A gasoline bus weigh-
lb. in frequent-stop service can make only
miles per gal. of gasoline, or 5.5 cents per mile,
and the oil and the grease cost about 1.5 cents addi-
it has therefore a total power expense of 7.0
per mile or 4.7 cents more than the trolley bus.

additional tables are given in Mr. Thirl-
article showing investment, fixed charges and
cost for different service conditions, varying
to very light traffic, from which the
stated at the beginning of the article are
drawn.

APPENDIX 3

Quotations from Walter Jackson's lengthy article on
The Place of the Bus are given herewith.

of the motorbus are rarely displayed
practical operation, for the reason that
which buses are most suitable are
g from the basic standpoint of
ness. The jitney operator,
, prefers to pass on the traffic that can best
railway along
effort. On the other hand, if the trac-
of the bus are exploited by the street
company itself, the desirable results ensue;
although rarely self-supporting, will
the railway
and be worth all or more than all profit.
bus is easy in comparison
for the same populations. . . .
the practical success of for-
and of premature or specu-
country. Another reason

hardly touched upon at the time, was that for the last decade or more no British road has built a track extension into thinly peopled territory if it could secure the right to build up such districts through a bus service first.

Approximately 29 electric railways in the United Kingdom are owned and operated as individual companies by the British Electric Traction Co. Of these, about one-half operate motorbus services.

Most of the British Electric Traction Co. services are of suburban character. Where tramway and bus route overlap from the center of a city up to or near the end of the car line, an extra high fare is charged to keep the facilities of the motorbuses for the long-distance suburban riders for whom they were inaugurated. In the opinion of this company's officials, the time for the tram is when the business has grown to the point of justifying, say, a 10-min. headway.

An idea of the importance of the British Electric Traction Co.'s bus operations can be gleaned from the fact that for the fiscal year ended Dec. 31, 1918, it operated on the systems named close to 300 buses and carried on them 19,000,000 passengers, exclusive of those carried with 700,000 bus-miles in the London district of the British Automobile Traction Co. for which no "passengers-carried" data are available.

The references to the bus undertakings of the British Electric Traction Co. are sufficient to establish the fact that the coordination of the car and the bus is not a chimera. In addition to these privately owned coordinated services, the United Kingdom has a larger number of privately owned all-bus systems, ranging from tiny rustic livery undertakings and feeder services for steam-railroad stations to the enormous system of the London General Omnibus Co.

In the year 1918, the buses of London carried the impressive number of 682,000,000 passengers; the underground lines carried 699,000,000 passengers and the street railways 992,000,000 riders, although the cars have but two good points of contact with the business and the pleasure area of the world's metropolis.[10]

Although British unit costs are different from our own, there is much that can be learned by studying comparisons of car and bus operations in Great Britain, particularly where the figures relate to the respective operations in the same community and under the same management. These figures will show that, wherever the services are coordinated instead of competitive, the number of passengers per vehicle-mile is usually much less on the bus than on the car, clearly indicating that the buses are being used for light-traffic routes. Furthermore, the earnings per bus-mile and the receipts per passenger are generally in excess of like classifications on the electric railway, because the average ride on the bus is longer and the rate of fare on the bus is higher. The schedule speeds of the buses are almost always higher than those of the cars, not on account of superior flexibility or higher maximum speeds, but because the buses average fewer stops per mile and have a much larger proportion of their runs in suburban territory or open country.[11]

To develop the possibilities of the coordination of motorbus operation with electric-railway lines to serve as feeders for interurban lines, the article states that the Stone & Webster interests made several applications in the State of Washington in 1915. The motorbuses were withdrawn in three instances after periods of service varying up to 18 months on account of operating losses. Quoting from the article[12] again

> The lesson to be drawn from these unsuccessful efforts to tie bus and interurban together obviously is that no such form of transportation can be successful if there are not enough customers to go around, if competition is unrestricted and if the direct bus service

[10] Electric Railway Journal, Feb. 22, 1919, p. 385
[11] Electric Railway Journal, April 5, 1919, p. 661
[12] Electric Railway Journal, March 24, 1920, p. 55

is preferable, whether from a time, money or comfort standpoint, to the use of two kinds of transportation. The amount of traffic carried did not justify the service, even after the bus is credited with bringing some patrons to the interurban. At the same time, if the bus did not make any money for the railway it had the important, though negative, virtue of preventing it from losing far more on the construction of a track and line for the distance under consideration.

It is also clear from these experiments that so long as irresponsible, free-for-all competition is permitted, the public will not enjoy that reliability of service and liability for accidents that are possible only through an established transportation undertaking.

The fourth, and surviving, route served by the Stone & Webster interests is of entirely different character, its purpose being to afford a through bus service between Seattle and Bothell, Wash., a distance of 16 miles over well-paved highways. This line was opened in November, 1915. Up to June 26, 1916, it had to compete with a five-car company, but by Oct. 10, 1916, the last jitney operator had disappeared. The Seattle-Bothell route is an example of a clean-cut bus-line from a large city to rather distant outlying communities that have no electric-railway service.

A significant fact is that few users of this route took advantage of the 5-cent fare and free-transfer privilege that would have enabled them to save money on the 5 miles between Cowen Park and the city depot at Fifth and Pine Streets, within Seattle. Consequently, the inter-line arrangement with the Seattle electric railway, then under the Stone & Webster management, was canceled Aug. 1, 1917.

This is in accord with much British experience. Most of such passengers from outlying communities desire to reach the heart of the city as quickly and as conveniently as possible rather than go through the bother of transferring from one vehicle to another at the terminus of the trolley line. Where a higher rate of fare is charged on the bus than on the car, a procedure necessary in any case, the bus will not be slowed down too much within the city through use by short-ride passengers, while the facilities remain available for the out-of-town riders for whom the buses were specifically installed.

Further installations in other sections of the Country are described also in the article, and it is stated that

> Experience abroad, and here as well, indicates, however, that people will pay a higher fare on the buses if the latter can offer noteworthy advantages in speed because of long non-stop runs.
>
> Within the limits of this article it is not practicable or desirable to list all the cases where electric railways have instituted bus services either directly or in cooperation with realty-development companies, manufacturers and other parties, but one may say confidently that today both roads and vehicles have improved to the point where requests for service to thinly peopled districts can be best and most cheaply satisfied by the installation of the motorbus.[13]
>
> The necessity for electric railways to concern themselves with the motorbus and its possibilities is clear from the dire situation that has arisen in New York City. As the reasons for the municipal bus-service there may not be so well understood outside of New York City as they are to residents of that city, a brief survey of this development may be clarifying.
>
> The greater part of the electric-railway mileage in the Borough of Manhattan, New York City, is on the underground-conduit system. This system, compelled by city ordinance, was much too costly for the electrification of certain routes that had lost their traffic importance with the decline of the ferries. Indeed, by 1913 several miles of practically hopeless trackage had been removed from the streets by order of the city. This year also marked the substitution of the storage-battery car for the horse car on such unelectrified trackage as remained.
>
> At no time did these storage-battery cars make any money, even when operated under such modest conditions as those of the Third Avenue Railway System, which used both new cars and rebuilt horse-cars. In May, 1916, when this company was operating the now defunct 28th & 29th Street Crosstown Railway, the operation and depreciation expense of a 16,000-lb. 24-seat car was 29.1 cents; whereas, the revenue was but 20.9 cents. This cost might have been brought nearer the point of subsistence if these cars had been operated with but one man each. The city ordinance that barred this practice with a slow car traveling on a fixed route does not apply evidently to the operation of the faster jitney buses that can twist and turn at will.
>
> With the further increase in costs due to the war, the New York Railways Co. in particular, found the burden of these storage-battery lines too great to bear at a 5-cent fare. Application to permit certain discontinuances therefore was made by the receiver on Sept. 19, 1919, before Judge Mayer of the United States District Court, Southern District of New York. The application was granted at once, with the result that on Sept. 20, 1919, the Madison Street, Sixth Avenue Ferry, Avenue C and Spring-Delancey Street routes ceased to function. The answer of the city administration was the installation of a "scratch" bus service, which, despite obvious shortcomings, has given the public more and faster service than was received before. The fare remained at 5 cents; but, as will be pointed out later, this is made possible only by a tax on the community as a whole.
>
> A portion of the Spring-Delancey Street line was restored Feb. 1, 1920, chiefly for transfer reasons, but it is doubtful whether the other routes ever will be. The fact must be faced that the railways on these and similar streets have become obsolete. Storage-battery two-men-per-car operation had proved both too slow and too costly to justify frequent service in territory where almost all of the traffic was of a short-ride character. The narrowness of some of the streets traversed had also been a factor in discouraging a renaissance of these lines following the elimination of the horse car.
>
> All in all, then, the policy of substituting motorbuses for the cars was the only correct one from a transportation standpoint under the conditions as they existed. It is doubtful whether any increase in fare would have done the railway operators any good. While a proposition from them to operate buses might have met with more favor, a higher fare than 5 cents would have been inevitable, since the cost per seat furnished is at least as high on a bus as on a battery car.[14]
>
> In the early days of the jitney it was fondly believed that liability bonds, taxation and other imposts would make the continuance of such operation impossible. As a matter of fact, the small touring-type jitney has largely disappeared, but it has been replaced by the more formidable jitney bus. So long as such buses are individually operated and run only on choice routes and during choice hours, their owners can show enough above actual costs to keep in the business. When investigation discloses that the same men have stuck to the game for 2 or 3 years, it is time to give up watchful waiting or passive resistance as good policy.
>
> Probably no city offers a better example of the jitney bus's tenacity than Newark, N. J. From 171 vehicles in June, 1916, to 402 buses in December, 1919, is one record; from 8,195,591 passengers in 1917 to 36,895,010 passengers in 1919 is another. These figures are de-

[13] See *Electric Railway Journal*, April 24, 1920, p. 850

[14] See *Electric Railway Journal*, May 29, 1920, p. 1088

[illegible] and safety of vehicle that have been characteristic of stage operation.

Mark now the change in his status if he decides that it is more profitable to carry more passengers at the street railway rate. He is no longer a hackman, temporarily renting his vehicle for the exclusive use of the first patron or group of patrons. His vehicle becomes an omnibus, literally a carry-all, whereby he not only cuts deeply into the earnings of the street railway but is also morally bound to accept the same obligations and burdens as the street railway.

The many novel problems involved in this transition, with its concurrent appeal to the public's appetite for low-cost service regardless of high-cost prices, are only now nearing solution in Great Britain. Yet the electric railways of Britain, so largely municipalized, did not have to meet the "Here's a chance to get square" tactics that are characteristic of conditions here. It simply has proved easier to control an industry that has a fixed track with some claims to right-of-way than one whose pathway is the common road.

In spite of the commendable cooperation that has been manifested recently between electric railways and civic committees, notably in the cities served by the Eastern Massachusetts Street Railway, there is no reason to expect the permanent elimination of the competitive bus through any other tactics than the giving of headways that are short enough to wipe out the jitney driver's margin of profit.

The argument is developed in the article that the responsibility for all mass passenger-transportation should be placed on one agency only.

In the article it is shown that practically every kind of motorbus operation costs more than modern car service on a well-traveled route, proving that at present costs the bus may supplement but cannot, from an economical point of view, supplant the electric railway upon the basis of equal fare and responsibilities. In concluding this survey of the place of the motorbus, Mr. Jackson summarizes the position of affairs as follows:[10]

(1) No service duplicating railways should be operated except for traffic-relief purposes

(2) Such service should be given by the local railway system

(3) Higher fares should be charged, preferably on a distance basis, wherever the bus offers superiority in speed and accommodations and also wherever it serves districts that are too sparsely settled to justify a permanent way

George A. Green, at the time general manager of the Fifth Avenue Coach Co. of New York City, in an article on Motorbus Transportation in New York City,[9] after describing the organization of that Company, makes the following observations in relation to the future possibilities of the motorbus:

It already has been pointed out that motorbus operation is a comparatively new art. The possibilities of improvements are practically unlimited. This applies to design for greater comfort and convenience as well as to economy of operation. The bus requires a minimum investment in garage and repair facilities, and its low unit cost is a powerful argument in favor of its adoption. Unquestionably, if a motorbus service is to realize its possibilities of financial success, it must be backed up not only by ample resources but it also must develop a highly specialized organization. The engineering force and the management must have specialized experience, for the motorbus traffic-demands are distinctly special.

Employes must be trained in a branch of motor-vehicle operation with many distinct and unique peculiarities, for which the operation of neither the auto-

mobile nor any form of transportation affords suitable experience. One of the chief differences between the bus and other forms of transportation is the matter of flexibility. As a matter of fact, we prefer to train men for drivers who have never had automobile driving experience. Furthermore, we find that railroad operatives, while they possess useful knowledge, must forget so much that, on the whole, it is more satisfactory to employ men without this experience.

In my opinion the wisest policy, both from a financial standpoint and the service results to the city, is to entrust a single, well organized and equipped company, possessing ample resources, with the development of a unified motorbus service. Parceling our streets to two or more companies will never provide the Pullman-car service that the true motorbus can give. The actual result of any form of competition must be multiplied fares and no transfers. With a unified system there can be no harmful monopoly, for the fare should be determined by the authorities and the company should be under public regulation, but so-called competition from a public-utility standpoint means bad service and financial failure. Cities cannot be prosperous without efficient utilities and utilities cannot be efficient without prosperity.

Clearly, where car tracks do not already exist, the most careful thought should be given before they are installed. Apart from this, from a public service as well as an operating point of view, there can be no question as to the possibility of using buses for (*a*) extending the service of existing car lines by bus system into the outlying districts through the introduction of transfer privileges between the two and (*b*) extending service, the conditions of the streets permitting, into the outlying districts without transfer service between buses and cars and without disturbing the present local business or business logical to the existing car lines, by permitting the buses to operate beyond the present outlying terminus of street cars and by diverting the buses to other parallel routes after reaching such outlying terminus.

APPENDIX 4

Under the title Teuton Trolleys Handle Freight, and a sub-title War Experience and Higher Costs for Fodder and Fuel Expected to Extend the Use of German and Austrian Tramways, the following[21] is stated:

A recent paper by Wilhelm Neumann, councillor, Austrian State Railways, read before the Austrian Engineering and Architectural Society, discusses encouraging possibilities for the further development of freight haulage on street railways. At the opening of the World War, the Vienna tramway system installed a track connection with one steam terminal to take over the passenger traffic released by the closing of the Stadtbahn to such business. The next step was to make use of these connecting tracks for freight.

The pressure for freight haulage on the street railways of Germany evidently was less, for it was not until December, 1916, that the War Department sent out a questionnaire to learn their facilities for freight business. Such business was less of a novelty to the German than to the Austrian electric railways. The latter had handled freight only spasmodically, whereas the Germans, as long ago as April, 1903, were moving freight on 60 of the 148 tramways in the country. Others were not doing so purely because of franchise restrictions.

In those days, also, the cheapness of horse transport and the cost of rehandling were the limiting factors. However, by 1913, 60 out of 135 Prussian street railways and 19 of the railways in the other German states were handling freight. These 79 companies then had 2600 cars for package mail and freight, of which 964 were regular freight cars, averaging 6 metric tons (6.61 net tons) each in capacity.

CONCLUSIONS REACHED BY GERMAN ROADS

According to chief engineer Winkler of Charlottenburg, Berlin, the German roads before the war had reached the following conclusions on the subject of handling freight:

Street railways should be considered freight feeders to the steam lines and should have direct or indirect connection with them. Car interchange is impracticable because of the sharper curves, smaller clearances, narrower wheel treads and coupler differences of the street railways. The use of sub-trucks, even if clearances are ample, is of but limited application. Trans-shipment is then necessary, and for this labor-saving devices should be used as much as possible. The freight was usually hauled in a train consisting of one motor-car and two or three trailers. Most freight service was handled at night.

The war led to a tremendous development of trolley freight. In February, 1918, practically all haulage on the electric lines was with trailer cars. In some cities garbage transport was instituted. Dusseldorf was the only city in which a package business was conducted. Most of the roads confined their efforts to carload transfers between the steam railroads and large shippers. Generally, the freight trains were run at passenger-car speeds and were often interpolated with passenger service. A disadvantage found with wagon trailers on their own wheels was the low speed of 4 to 8 km. per hr. (2½ to 5 m.p.h.), compelled by the character of their spring-suspension and brakes.

The tariff changes are usually based upon the capacity, not actual load, of the trailer and the distance run. The prices are considerably below those charged for horse drays. An auxiliary saving, due to easier transfer from steam to electric cars, is the quicker release of the steam cars, made possible by the better use of mechanical transfer-devices. More freight business by electric railways would not only enlarge the steam-railroad revenues but give a better use factor of men, powerplant, truck and line.

HEAVY WAR TRAFFIC IN VIENNA

Referring to Vienna, Mr. Neumann said that up to February, 1918, the local street railways had made 110,000 car trips, the equivalent of 310,000 wagon trips. For the same amount of work 350 horse trucks or 100 motor trucks would have been needed. A great variety of materials was handled, the local distribution of mail being especially successful.

[21] See *Electric Railway Journal*, May 22, 1920, p. 1062.

Discussion of the Chicago Tractor Meeting Papers

THE discussion of the papers presented at the Chicago Tractor Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort.

THE GENERAL-PURPOSE FARM TRACTOR

BY C. M. EASON

THE author divides the history of the application of mechanical power to farm work into three periods, reviews each one and comments upon the various phases of progressive development that influence the type of tractor most desirable for satisfying present needs. The requirements of farm work are outlined, and the different types of tractor built and being constructed to meet these demands are reviewed, discussion of large versus small tractors, type of drive, power needed, control, methods of operation and the factors constituting general-purpose service being included.

So far as adopting the tractor for farm usage is concerned, the author believes that the present limitation of such utilization lies with the tractor industry and with tractor engineers, rather than with the farmer. [Printed in the June, 1923, issue of THE JOURNAL.]

THE DISCUSSION

N. S. JOHNSON:—We began with the idea that it is possible and practicable to make a general-purpose tractor, that we could develop a power machine and the implements that go with it so that the operator could attach and detach them quickly, the idea being to increase the production per man to the greatest possible extent and to reduce the cost. After several years we found we were getting very complicated machines. When the power machine became heavy enough to do some of the heavy work, it was too heavy and powerful for some of the lighter jobs. There were limitations as to the weight of the machine that could be used profitably in horticulture. A machine that would cultivate row crops to the best advantage was too light for some of the other farm work. Finally, we developed a power machine to which practically horse-drawn types of implements can be attached, such as cultivators and other special equipment, that are very much lighter and cheaper to produce than are regular horse-drawn machines. We believe we have made some progress, but we have not by any means reached the point where we think the problem has been solved. It is a very intricate problem.

CHAIRMAN A. W. SCARRATT:—If we are to extend the use of power farming, we must make the power unit available to the present horse-drawn implements. An added phase concerns the question of whether present horse-drawn implements are capable of withstanding the severe operation they must endure when pulled by an independent power unit. A power-driven unit is not flexible in the same way that a horse is. To attain the ultimate result will require cooperation between the manufacturers of the power unit and of the implements. The Farm Equipment Association and the tractor builders must correlate their views.

DENT PARRETT:—Our experience with light cultivating machines was gained on a large farm. We found that our small machine could be kept busy almost every day of the summer; a larger tractor on the same farm was used only for a few days. This gives an idea of the comparative utility and demand for a machine that can be used for all the other operations. Some things are done ordinarily with two and three-horse teams; the lighter work, such as cultivating and haymaking, can be done with the light machine. A tractor to do this work must be well made, because a general-utility tractor would run several times as much per year as the tractors we have now.

CHAIRMAN SCARRATT:—Farming requirements vary according to the district; in the large grain-producing sections in which there is little diversity of farming and in which large acreages must be covered, our present tractors nearly fill the requirements of the farm. Even a three-plow tractor, and surely nothing larger than that, would not be a profitable size of machine to use for diversified work. What we must think about is the creation of a new small-size machine of not more than two-plow capacity that will do a wide variety of work. The increased number of hours of use that a light machine would have and the necessity for high-class construction to make it able to withstand this increased service are important matters. The cost of the machine will increase with the increase in quality. Whether it will be possible to bring out a flexible light-weight machine and sell it at such a price as will make it a real competitor with present power and horse-drawn implements will require serious study.

J. B. DAVIDSON:—So long as the corn-belt farmer must use animal power to cultivate and gather his crop, he will not find a very large place for mechanical power. The solution of the problem depends on taking into account some of the most important factors involved, one of which is the realization that the cultivation of corn is a precision operation. A tractor cultivator must go just where the operator wishes it to go without any doubt; dangling lines, flexible connections and the like, are a disadvantage. Four rows of corn can be cultivated in one operation just as well as two if the four rows have

been planted in one operation. There is also a possibility of employing better farming methods. With plenty of power there is little reason that weeds should start in the corn field. The main purpose of cultivating corn is to kill weeds.

C. C. TRUMP:—I agree that the steam tractor as it was is on the decline, but it seems that there still is a place for the steam tractor.

C. M. EASON:—About 12,000 or 15,000 large-size tractors for threshing and for similar work are being built each year; it is a steady business.

MR. TRUMP:—I referred to something a little different from the ordinary conception of the steam tractor. Having to do with uniflow steam engines, I have had an opportunity to cooperate with one of the tractor companies in developing a light steam tractor. We designed the engine for it, after having designed the engine for a truck. We found that, although there were difficulties with the engine, the main difficulty was with the boiler and the combustion system. Development work of this kind has been going on for about 10 years.

It has been suggested that, since we must consider the fuel problem, the waste products of the farm should be used for fuel. A steam boiler that is properly designed will burn wood, straw, corn, oil or coal. If the average use of the tractor is only 50 days per year, we must consider ways to reduce the interest charges by increasing the use. It would seem to me that the steam tractor could be used during the winter for furnishing power, light, hot water and, by proper connections, could store heat for houses. We all are familiar with the possibilities of the flexibility of control of steam power for cultivating and for work of that kind. It seems to me that such a tractor could be worked out, and that there are possibilities in this direction that engineers have not taken into account. The types of engine, boiler and combustion system are being improved and I believe are available for a light machine, suitable for two or three plows and general-purpose work.

A MEMBER:—I am interested in the light-type steam tractor. We have found that the steam-power tractor using distillate or low-grade fuel works satisfactorily under high-pressure steam.

CHAIRMAN SCARRATT:—The steam tractor certainly offers interesting opportunities for further development in the future.

NEBRASKA TRACTOR-TEST ANALYSIS

BY OSCAR W. SJOGREN

A COMPILATION of all results of the tractor-testing work at the University of Nebraska is presented by the author, who specifies the equipment used and discusses the subjects of the proper rating of tractors, belt speeds, weight distribution, tractive efficiency, wheel slippage, piston displacement, fuel and water consumption in considerable detail supplemented by illustrations. The defects of tractors are divided into the three main groups of engine, accessory and chassis, and enumerated, comment being made thereon.

Three general recommendations for remedying these defects are stated and a statistical record of the results secured during the three seasons when the tests were conducted is included. That a better product is one of the direct results of the testing program is indicated by the statistics presented in Table 1.—[Printed in the June, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN SCARRATT:—Professor Sjogren's paper is distinctly divided into two parts; one pertains to the graphic analysis of the Nebraska tractor-test results from a design standpoint; the other is a statement of the nature of the troubles encountered during the test. How many builders sent their experimental machines there to get an idea of what the machines could do? The number of troubles and their variety are such that the builders and their engineers should profit by them. Judging from the decrease in the kinds of trouble encountered in 1921 and 1922 as compared with 1920, they have done so.

I am impressed by the relative drawbar efficiencies of tractors, with respect to tractor weights. Undoubtedly, many of the tractors that made the best relative showing probably can attribute a good share of it to a wise selection of drive-wheel equipment. The preparation of the track on which the drawbar testing was done has a bearing on the efficiencies recorded during the tests, and the difference in tractor ratings when machines of different companies are equipped with the same make and size of engine is definite proof that there must be some standard basis of tractor rating; it is not logical or fair to the farmer that machines which are driven by the same make and size of engine should carry different ratings. The difference in efficiency due to transmission design does not warrant any extravagant claims on the part of any builder as to the performance of his machine. Gear-driven machines versus live-axle-driven machines should be discussed, as well as Professor Sjogren's chart showing the relative efficiencies of the different types of engine, particularly the common L-head type as compared with other types.

H. A. HUEBOTTER:—Fig. 1 of the paper shows that, on the basis of the proposed horsepower rating of 80 per cent of the maximum power, the belt rating of about 70 per cent of the tractors tested must be reduced. On the other hand, the drawbar rating of only 30 per cent will have to be lowered. Three things may have some effect on the drawbar rating in proportion to the belt-horsepower rating. In the first place, the builder has not the opportunity for measuring drawbar horsepower to the same degree of refinement that he can measure engine power in a laboratory. Hence, he is conservative in his drawbar-horsepower rating to be on the safe side. Secondly, the tractor may have been limbered-up more for the Nebraska tests than it would be for field tests around an experimental farm or at the factory. The third point, which affects the mechanical efficiency of the tractor from the engine to the drawbar, concerns the power losses between the wheel and the ground. We can deliver considerably more power to the wheels than we can get at the drawbar. The difference between the power at the wheels and that at the drawbar is usually known as the ground loss. It may consist both of slippage between the wheels and the ground and of the power required to move the tractor.

What is Professor Sjogren's estimate as to the field conditions of soil that are approximated in his composite track of earth and cinders? What field conditions would require the same power to run the tractor idle as

[illegible] the lugs do not cut into the ground. Is that correct?

PROF. O. W. SJOGREN:—Yes.

MR. HUEBOTTER:—[illegible] the lugs enter the ground at all. If the tire runs directly on the ground, slippage will be reported even if there is no actual shearing of the ground. With regard to data on the development of the power rating for tractors, what is the horsepower in terms of cubic inches of piston displacement per minute?

PROFESSOR SJOGREN:—That was brought out in Figs. 17 to 19. Regarding the comparative ground condition in the field that would about equal the ground condition of the track, that is practically an impossible question to answer because field conditions vary so much. Tractors do over the track time and again; this chews it up to such an extent that we do not get actual field conditions. To counteract this, we attempt to unify the conditions as much as possible by the use of drags, harrows and packers whenever we feel it is necessary. We do not use either packers or harrows in all cases or at all times; there are limits to the condition of the track with regard to moisture and compactness. Roughly speaking, the condition of the track during the tests might be represented by a plowed field with the surface in medium condition as to hardness or compactness with the lower part fairly compact.

MR. HUEBOTTER:—Is it more like a stubble field than soil?

PROFESSOR SJOGREN:—Yes.

CHAIRMAN SCARRATT:—We can all appreciate the difficulty of maintaining a uniform track, because nothing is any more variable than the fields that tractors work in, nor as much in moisture content as to anything else. As to piston displacement as a basis of rating, that would seem to be unreasonable in view of the wide variation that exists in the piston displacement per horsepower delivered of the different engines that have been tested. It sometimes seems almost ridiculous to assume any piston displacement as a basis for judging the horsepower of an engine, because there are such great differences in the performance of engines.

We have a criticism pertaining specifically to the methods of determining drive-wheel slippage, followed in the Nebraska tests. Professor Sjogren has stated that drive-wheel slippage is based on the outside diameter of the wheel with the lug equipment attached. With that it would be easy to attain 100 per cent traction because of the little penetration of the steel equipment into the ground would show up as a certain amount of slippage. Whether or not the future work should consider a diameter [illegible] than the maximum outside diameter is a point that we should determine. In calculating the traveling speeds of tractors, it is customary for most builders to consider the outside diameter at the drive-wheel rim as being the diameter to use; assuming that the lug equipment does not penetrate, the amount of grip is obtained in that way.

Concerning the method of determining slippage by counting the revolutions of one drive-wheel without consideration of the revolutions of the opposite drive-wheel, there is a question whether that is a proper way to determine the distance traveled and the amount of slippage.

R. F. VOGT:—A most serious error in testing drawbar horsepower at Lincoln, Neb., was made by the official testers in counting the revolutions of only one tractor drive-wheel to judge engine speed and slippage. In all Nebraska Official Tractor Tests made in 1920 and 1921, at Lincoln, the revolutions were counted on one drive-wheel only, thus neglecting the action of the differential in the tractor which, of course, makes it possible for one drive-wheel to slip more than the other when the tractor is pulling a heavy load on the more or less hard surface of the test track. The engine speed was calculated from the revolutions of one drive-wheel and the gear ratio of the tractor. As the drive-wheel on which the revolutions were counted slipped more or less than the other, this may have caused the calculated engine speed to vary from the actual speed.

PROFESSOR SJOGREN:—In the present method of conducting the maximum drawbar test the time and slippage observations are taken between stations 400 ft. apart. The time is taken by a stop-watch and the number of revolutions of the drive-wheels is secured by electric revolution counters, one of which is mounted on each drive-wheel. An electric speed-counter attached to the engine and with its indicator mounted in the testing car is used for observing the engine speed. The governor is set to allow the maximum power or full throttle-opening. The load is adjusted so as to keep the speed of the engine at approximately the rated figure. This enables us to secure much more accurate results than was possible before these improvements were installed.

Table 2 is a record of drive-wheel revolutions in 400 ft. as taken from the log sheets of several tests run after the counters were installed.

MR. VOGT:—The test track at Lincoln that was used for the Nebraska Official Tractor Tests was, in my opinion, very unsatisfactory insofar as presenting uniform conditions for all the tractors tested. To get the greatest satisfaction, the test track should have been plowed-up after each test run, especially after testing very heavy tractors. This was not done and consequently some light and some medium-weight tractors showed greater slippage than did others of the same weight and wheel equipment.

TABLE 2.—NUMBER OF REVOLUTIONS OF DRIVE-WHEELS IN 400 FT.

Test No.	Tractor No.	At Rated Load		At Maximum Load			
				In Low Gear		In High Gear	
		Right Wheel	Left Wheel	Right Wheel	Left Wheel	Right Wheel	Left Wheel
[illegible]	7	[illegible]	[illegible]	30.0	30.2	35.6	34.7
[illegible]	[illegible]	[illegible]	[illegible]	32.7	34.2	32.1	34.9
[illegible]	[illegible]	[illegible]	[illegible]	38.7	39.2	42.8	43.2
[illegible]	7	[illegible]	[illegible]	30.0	29.9	29.8	29.9
[illegible]	[illegible]	[illegible]	[illegible]	23.0	22.9	25.6	27.0
[illegible]	[illegible]	[illegible]	[illegible]	35.9	36.7	35.9	39.8
[illegible]	[illegible]	[illegible]	[illegible]	30.7	31.6	30.2	29.8
[illegible]	[illegible]	[illegible]	[illegible]	26.4	27.6	25.9	25.6
[illegible]	[illegible]	[illegible]	[illegible]	26.0	26.9	24.1	23.7

PROFESSOR SJOGREN:—We realize better than anyone else that the testing track is not anywhere ideal and we do not want it ideal. We are required by law to test the tractor under actual field conditions or conditions approximating them, and while the track used is not the most satisfactory, a special sand clay track would be far more remote from actual conditions encountered by the farmer in the operation of his tractor.

With regard to slippage of the drive-wheel, whether it is taken at the point of the lug or at the rim, our last reports give the percentage at both the point of the lug and at its base, which is the rim of the wheel. I am not positive that either method is correct. It may be that the point of penetration should be the point at which slippage should be taken, but many variables enter. I think the two sets of figures we give are the nearest that can be obtained. Mr. Vogt's criticism did not refer to the method of determining the horsepower or its value, but pertained to the method of securing the data relating to wheel slip and the engine speed in the maximum drawbar tests, which are merely furnished as supplemental information to the reports.

As regards the counting of drive-wheel revolutions to determine slippage, we can now count the revolutions on both drive-wheels to one-tenth of a revolution. We have also installed equipment that enables us to determine the engine speed directly during the run without reference to the revolutions of the drive wheel. We have our test machine arranged so that, by electrical apparatus, the man in the machine can count the revolutions of both drive-wheels and can adjust the load to keep the engine speed at the exact rated number of revolutions per minute. These electrical counters indicate that the number of revolutions of each of the two drive-wheels does not vary more than 5 or 6 per cent; that is, the slippage does not vary more than this amount. The records were obtained under conditions of track that varied from very dry and loose to wet and are an indication of the slip during the regular and maximum drawbar tests.

The high tractor efficiencies shown in the charts are for the crawler type. We have some high efficiencies for the wheel type but not nearly so high as for the crawler type. This probably is not due so much to the equipment as to the way in which the belt power is taken from the engine.

We welcome constructive criticism of our methods, so that we can improve them. We had nothing to guide us in building equipment or in devising methods of procedure during the first two years of testing. We take advantage of every breathing spell and all constructive criticism to help us to improve conditions and equipment.

B. S. PFEIFFER:—In the charts on fuel consumption, what kind of fuel was used?

PROFESSOR SJOGREN:—Both kerosene and gasoline. The lowest figure on kerosene was 0.63 and the highest, 1.40 lb. per b. hp-hr.; on gasoline, the low figure was 0.65 and the high figure, 1.13 lb. per b. hp-hr. Very few tests are in the high class; more of them run about 1 lb. per b. hp-hr.

MR. HUEBOTTER:—Professor Sjogren has an unparalleled opportunity for seeing the relation between the brake horsepower and the cubic inches of piston displacement per minute. The big variable in the horsepower equations is the mean-effective pressure. If we get an average value of the brake horsepower from this series of tests, it may give us a chance to establish a formula for this type of heavy-duty engine. Does Professor Sjogren compute the mean-effective pressure in his test results?

PROFESSOR SJOGREN:—No; the engines are not equipped to give it. I have made an attempt, however, to figure the rating based on the cubic inches of piston displacement, but it varies so that there is no basis of comparison.

CHAIRMAN SCARRATT:—How did Professor Sjogren determine the brake horsepower of the engine in getting at the cubic inches of displacement? Is it based on the brake horsepower delivered to the dynamometer or at the crankshaft?

PROFESSOR SJOGREN:—It is that delivered at the dynamometer.

MR. TRUMP:—Were any heavy oils and fuels tested, or any steam tractors?

PROFESSOR SJOGREN:—No, if by heavy oil you mean anything heavier than kerosene.

MR. TRUMP:—Is your equipment such that you can test machines that burn heavy oil?

PROFESSOR SJOGREN:—Yes.

CHAIRMAN SCARRATT:—From the wide variation in the governor regulation, it seems almost as though some of these engines would perform better if they were not equipped with governors. What does Professor Sjogren think a governor really ought to do in the way of speed regulation?

PROFESSOR SJOGREN:—I can relate what has been done. An engine was brought there that had a speed regulation of less than 1 per cent either way from its rated speed, that is, above or below its specified speed, but that is so nearly ideal that we cannot hope for such perfection. I think a governor should maintain the engine speed within 5 per cent, plus or minus, of the rated number of revolutions per minute. We have had governors that would do that very easily.

CHAIRMAN SCARRATT:—What is the extreme variation?

PROFESSOR SJOGREN:—It is about 50 per cent.

A. H. BATES:—I believe that tractor builders have been thinking more about the rating of tractors during the last year than they did formerly. If we rate a tractor on the present S. A. E. Standards basis, that is, 80 per cent of the maximum belt power delivered for 2 hr., the rating cannot be checked easily and is not understood by the purchaser. Many builders, as shown by the 1923 tests, are rating their machines rather close to the maximum load that the machine will handle. For instance, one builder rates his engine at 30 hp., whereas its maximum output is only a trifle more than 32 hp.

The loads on the tractors with which I am familiar have been intermittent and testing an engine at the maximum or even at the rated power for a 10-hr. period possibly puts a load on the engine that the builder did not contemplate. If an electric motor designed for a certain temperature-rise for a 30-min. load is put through a 10-hr. maximum load test, it will burn out. That is one of the reasons why some of the tractors on test showed such a high water-consumption. Their radiators were designed for an average load, and the full load was put on them for the entire period.

CHAIRMAN SCARRATT:—I do not know whether Professor Sjogren's figures refer to water consumption as injected with the fuel or water added to the cooling system; one is a subject relating to carburetion and the other is a subject that relates to radiation. Radiators ought to be capable of cooling the engine adequately under a sustained maximum load, because the tractors must operate through a very wide range of temperature and of altitude conditions, and both have a very pronounced effect on the cooling capacity.

The purchaser should be able to determine the rating for himself. The rating prescribed should be one that we will all agree to use; then it ought to be possible for engineers to see that the sales departments of their respective organizations use that rating and are not permitted to use any other. The success of automobile companies is due largely to the cooperation of engineers and their advice as to what should be produced and what should be established as standard. The industry should establish standards on practical lines, talk the farmer's language so that he can understand and then make certain that the organizations adhere to them. Something that is clear and plain in the office should not be cast aside by the salesmen in the field; that is too confusing.

CHAIRMAN SCARRATT:—I am sure that all of the builders are aiming to produce a legitimate tractor, legitimately rated. The evidence of that lies in Mr. Sjogren's statement that shows the decrease in the number of tractors that failed to come up to the Nebraska test-requirements.

W. H. WORTHINGTON:—Possibly the greatest criterion of what the life of a tractor will be is the thinning of the oil by use. As I watched the tests at Lincoln, I was very much disappointed at the poor condition of the lubricating oil at the end of so short a period. We have been working on an engine in which, after 1 month and 24 days of operation at road building on kerosene, a severe test because of the variable loads, the viscosity of the oil was reduced 8 Saybolt sec. at a temperature of 112 deg. fahr. The oil viscosity was originally running 74 Saybolt sec. Regarding the tractor tests, is similar information available?

PROFESSOR SJOGREN:—No.

MR. WORTHINGTON:—Have you reached any conclusions as to the later tractors?

PROFESSOR SJOGREN:—No.

MR. WORTHINGTON:—The indications are that temperature control is gaining an important place in tractor design, the use of some system of control for the intake temperatures that will do away with a drop of temperature under lesser loads. The particular engine of which I spoke had an idling temperature, the lowest recorded, of 210 deg. fahr. The highest idling temperature is 290 deg. fahr.; the lowest full-load working-temperature is 175 deg. fahr. To overcome those conditions will solve the one great problem that confronts the user of our product toady; we can see the mechanical difficulties.

SCIENCE IN THE EVOLUTION OF INDUSTRY

rtation that caused the development

The industry has often been im-

For example, the time is not far distant, if it is not already here, when the uses to which our crude-oil supply is put will be restricted to those for which it alone is suited, such as lubrication. Hence, one of the greatest problems of the industry is to find a substitute for gasoline. Internal-combustion engines are now being made to use a heavier fuel than before, and those to use crude oil are being developed. Many experiments are being made on the use of other fuels. Alcohol, if free from water, can be mixed very successfully with gasoline in large proportions. The automotive industry faces many problems in the future, but its evolution will, like the others, be brought about as the automotive engineer and the scientist work together and attack increasingly difficult problems with the more and more efficient tools of science.—From the inaugural address of S. W. Stratton, president of the Massachusetts Institute of Technology.

Wire Wheels

By W. W. Davison[1]

Buffalo Section Paper *Illustrated with* Drawings and Photographs

WIRE wheels, having been used exclusively on bicycles, naturally were adopted as standard by the builders of the early types of automobile. But as the automobile soon increased greatly in weight and as its builders believed that the best results could be attained by wheels of large diameter, wire wheels were found to be lacking in strength and were discarded in favor of wood wheels of the artillery type, which at that time were being imported from France. When, a few years later, wire wheels again appeared on some of the English models, the prejudice against them still remained and it was not until about 1914 that they began to find favor in the industry. Drivers of racing cars, however, continued to use wire wheels because they obviated the flywheel effect and lent themselves to quicker braking and accelerating.

Attention first was given to increasing the strength of the spokes, then to their shape, so that, whereas the spokes used in the first tests could withstand only about 6000 shocks, those now in use can resist upward of 1,500,000 shocks before breaking. These results have been obtained from the 25-deg. taper, bung-head type, made of 0.205-in. wire, swaged by gradually reducing the center of the spoke to 0.148 in. in diameter and then increasing it to its original size at the threaded end. The tests that the spokes must undergo are intended to duplicate the various lateral stresses and impacts received in service.

The sudden demand of 5 or 6 years ago caused the double or two-spoke lacing and other discarded and inferior makes to be marketed, and trouble again appeared, but the difficulty has been obviated by the triple-spoke wheels now in use. In addition to greater strength and ability to resist impacts, the advantages of wire wheels are said to include quick changeability and greater tire mileage, due to the resilience of the wheels, which assists in absorbing road shocks, and to the radiating by the spokes of the heat generated by the friction of the tires on the road. The method of driving also has been improved by the use of a corrugated taper drive that is described.

ALL are familiar with the velocipede and the bicycle, and most of us can remember when the velocipede was made entirely of wood, except the axles. The first bicycle, following the general lines of the velocipede, was equipped with wood wheels, but manufacturers soon found that wood wheels were not satisfactory because of the danger of breaking and the difficulty of making a wood wheel that would give complete satisfaction without undue weight. This type of wheel was soon discarded and all bicycles were equipped with metal wheels, in which the rims were secured to the hubs by steel-wire spokes. The wheels were almost universally of the type in which the spokes are secured to flanges at each end of the hub and terminate at approximately the center of the rim. The fact that there has been no change in this feature for the last 25 years is, I believe, sufficient evidence that such wheels are the best for bicycles that can be found.

The first automobile builders naturally followed bicycle practice and equipped their cars with wire wheels of the bicycle type; but owing to the fact that the automobile developed quickly into a large heavy vehicle, and also to the fact that automobile companies believed that large-diameter wheels would give the most satisfaction, it was discovered that wire-spoke bicycle wheels did not have sufficient strength. Attempts were made to bring out a wire-spoke wheel that would be sufficiently strong, but the manufacturers could conceive of no other way of doing so than by increasing the number of spokes, which were arranged as in the bicycle wheel, or more or less fantastically. The complexity of the spoke arrangement did not appeal to the popular fancy, and as wood wheels of the artillery type were imported from France about that time, wire wheels soon dropped into disuse and automobiles, beginning about 1903, were equipped with wood wheels, the only exception being buckboards, which continued to be made for 1 or 2 years after that date. Although automobile builders found that large-diameter wheels were not suitable for motor vehicles, they still retained the wood wheel rather than take the chance of returning to the old bicycle type. So far as I have been able to determine, there was no tendency at that time to use disc wheels.

About 1910 or 1911 motor vehicles imported from England were equipped with wire wheels that had all the advantages of the old bicycle type, that is, lightness, resiliency and appearance, without its disadvantages, but owing to the prejudice against wire wheels that had been created in the minds of the automobile builders and to the wheels being more expensive than wood wheels, the wire wheel did not take hold of the automobile industry until about 1914.

However, there is one exception to that statement; namely, the use of wire wheels on racing cars. As soon as wire wheels of sufficient strength were produced, drivers of racing cars without exception adopted them, because they obviated what is popularly known as the "flywheel" effect, due to the disproportionate weight of the wheel at the rim. The wire-spoke wheel, by avoiding this difficulty, lends itself to quicker braking and accelerating. The adoption of the wheels by racing drivers soon led automobile builders to look further into the matter and, since about 1914, the use of wire wheels on motor vehicles has increased rapidly in spite of the fact that, even though great attention has been given to production methods and the cost of manufacture, it has been absolutely impossible for wire wheels to compete with wood wheels on an even basis, the wire-wheel cost being approximately from 50 to 100 per cent more than that of wood wheels.

During this time automobile companies have been improving all the other parts of their cars and replacing wood wherever possible with steel, with the exception of a single firm that continues to use a wood frame to obtain lightness. The increasing use of steel naturally has led many companies to consider that wood wheels, which today are substantially the same as those of 20

[1] M.S.A.E. Factory manager, Wire Wheel Corporation of America, Inc., Buffalo.

[illegible] would be avoided and that steel wheels should be used. To meet this demand and to avoid the expense of wire wheels, there has been a tendency to employ steel disc wheels, which can be procured at approximately the price of wood wheels.

Spoke Breakage

The chief difficulty in the use of wire wheels for heavy cars during the pioneer days was the breaking of the spokes which was current in 1917 and rightly caused many complaints. An attempt, therefore, was made to provide spokes that would give the utmost service that could be expected of them. After several years of experimenting, testing and changing, we have developed a spoke which is, we believe, the strongest that can be made. The chemical composition, particularly the carbon-content of the spoke, was the first point to be attacked, and we soon found by physical and chemical tests that the composition of the spoke used in 1917 was not correct, but with the assistance and cooperation of spoke manufacturers, a spoke of surpassing toughness and [illegible]ency was produced.

Fig. 1 shows a series of spokes and Table 1 represents their chronological development up to the present, illustrating the type of head, body of spoke and the like.

In carrying out the tests we developed testing-machines so that we could determine accurately the best design and metallurgical construction of spokes. Fig. 2 shows a testing-machine for applying radial torque intermittently in both directions. We found the most efficient way to test the wheel was to place it under the strains to which it would be subjected in operating the car; that is, the strains that had to be met with when the clutch is thrown in and when the brake is applied. This we did by mounting the wheel so that the rim was clamped rigidly to prevent movement. The hub was mounted on a shaft that was oscillated to give the spokes the strains that they must withstand when a car is started or stopped. The first tests showed that a 4-passenger wheel, made with the best spoke procurable at the time, would not withstand more than 4000 of these shocks before beginning to break. We next developed tests with which the wheel could be subjected to as many as 100,000 shocks before a spoke would break. If we should consider, which I believe would be perfectly fair, that on an average 10 miles of actual operation the wheels of the car are not subjected to any of these shocks oftener than once per mile, this would mean that the wheels would be capable of giving service for 100,000 miles before difficulty would be encountered.

Table 1—Chronological Development of Spokes

Letter	Type	Diameter, In.	Taper, Deg.	Diameter after Swaging, In.
[illegible]	[illegible] Head	0.175	None	Not Swaged
[illegible]	[illegible] Head	0.175	None	0.156
[illegible]	Button Head	0.205	None	0.175
[illegible]	Standard Button Head	0.205	None	0.175
[illegible]	Bung Head	0.205	12	20 and 30	0.185
[illegible]	Bung Head	0.205	25	0.185
[illegible]	Bung Head	0.205	25 (long)	0.185
[illegible]	Bung Head	0.205	25 (long)	0.148
L	Bung-Head	0.205	25	0.175

However, this was not believed to be sufficient and we began to consider changing the shape of the spoke, since we found that the tendency was for the spoke to snap at the head end. Up to that time we had been using what is commonly known as a button-head spoke, in which, as is shown in Fig. 1, the diameter of the spoke decreases quickly from the head to the body; and it was at this point that most of the breakage occurred. We then developed a new spoke that avoids these sharp changes of diameter and, in the tests, wheels equipped with these spokes have withstood as many as 1,500,000 shocks before the breakage started.

Spoke Design

The spoke designated in Fig. 1 by the letter *k* and from which we obtained such excellent results in our tests, is what is known as the 25-deg. taper, bung-head

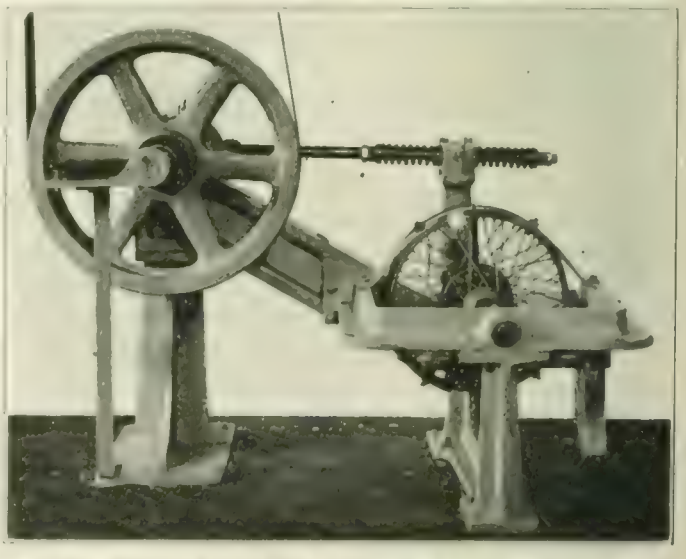


Fig. 2—Testing Machine for Applying Radial Torque Intermittently in Both Directions

type, made of 0.205-in. wire, swaged by gradually reducing the center of the spoke to 0.148 in. in diameter and then increasing it to its original size at the threaded end. The spoke holes in the hub shell are countersunk to conform to the shape of the 25-deg. taper head so that, when assembled, a perfect taper fit is obtained. After the spoke has been put under the necessary tension at the time the wheel is built, the head remains fixed in position relative to the hub shell by having the center of the spoke swaged to a minimum diameter. The vibration is transferred from the head toward the center or blade of the spoke, which bows back and forth under the load. Hence, breakage is eliminated by transferring the vibrations to and absorbing them into the blade portion of spoke, and reversely, to the rim, thereby preventing the localizing of a fatigue point.

As the tests were intended to duplicate the conditions a car must undergo, we anchored the hub of the wheel, as shown in Fig. 3, in a side-deflection testing-machine, applying a lateral load to the rim, reproducing as nearly as possible the strains that a wheel sustains as the result of side stresses and ascertaining the lateral resiliency of the wheel. A further test is to mount the wheel and subject it to a heavy blow at the rim from a pendulum, as shown in Fig. 4, to determine its action when skidding against a curb. When this test was carried to the breaking-point it showed without question that a blow which would have put a wood wheel completely out of commission will not destroy a wire wheel. This test is perhaps the closest approximation to the blow the wheels of a car would receive in a collision, and we have found the results of the tests to be borne out by actual road service.

In spite of their excellent performance and merit, wire wheels have been subjected to a great many criticisms. In many instances they have been well founded and are just. The manufacturers themselves have been partly responsible, as the engineering departments did not develop wire wheels as rapidly as motor-car engineers developed their products.

The question of spokes was of great importance, yet was practically neglected. The manufacturers believed that by increasing the number of spokes breakage could be prevented, but they disregarded the most important part, that is, the chemical and physical analyses of the steel used for making the spokes, also the type of head to be used and the amount of swage reduction necessary to spread the vibration over a wide area and to prevent fatigue from taking place at any one point. The manufacturing tolerances were too liberal; closer tolerances could have been used, but it was easier to work to large ones that allowed inspection departments to pass products that today would be considered unsatisfactory. The sudden demand for wire wheels in 1917, 1918 and 1919 created an opportunity for inferior makes to be marketed, such as those with the double or two-spoke lacing, which was discarded years ago and which had not been

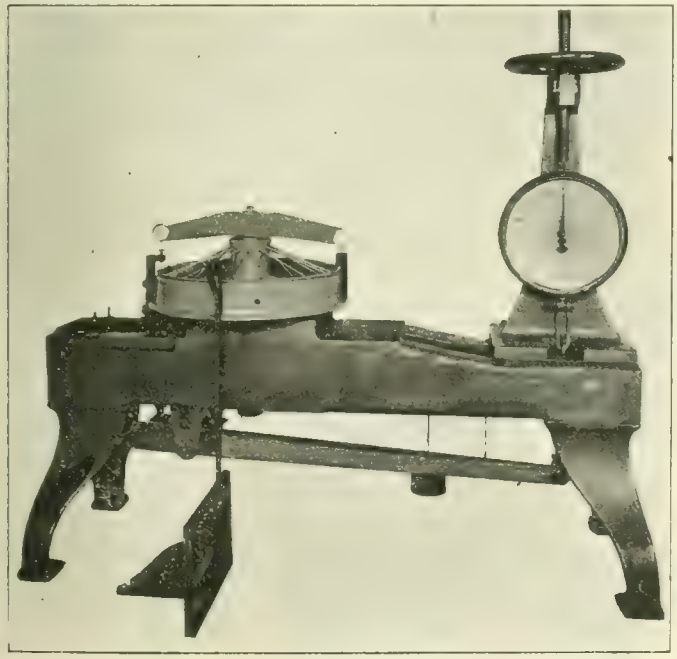


Fig. 3—The Side-Deflection Testing-Machine Designed To Reproduce Very Nearly the Strains To Which a Wheel Is Subjected in Service

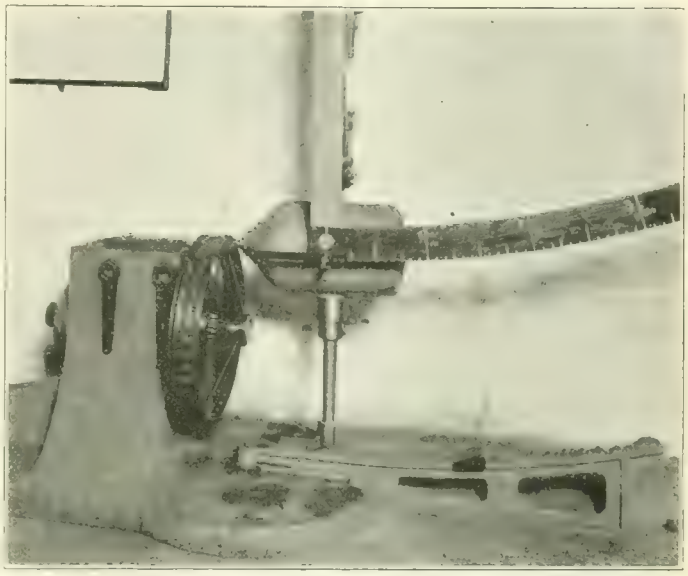


Fig. 4—The Pendulum Testing-Machine That Determines the Action of a Wheel When Skidding Against a Curb

designed to take care of the side stresses and strains that necessarily are to be expected in the wheels of heavy cars. The result was that spokes would loosen-up, squeak and break.

An endeavor was made to market a two-spoke wire wheel demountable at the rim and lacing through the metal felloe for a four-wheel equipment, but that type of wheel, owing to the narrow lacing zone of the felloe, did not give sufficient strength and satisfactory results could not be obtained except on light-weight cars. Wire wheels therefore were condemned by many persons; but the difficulty has been overcome by the triple-spoke wire wheels of today.

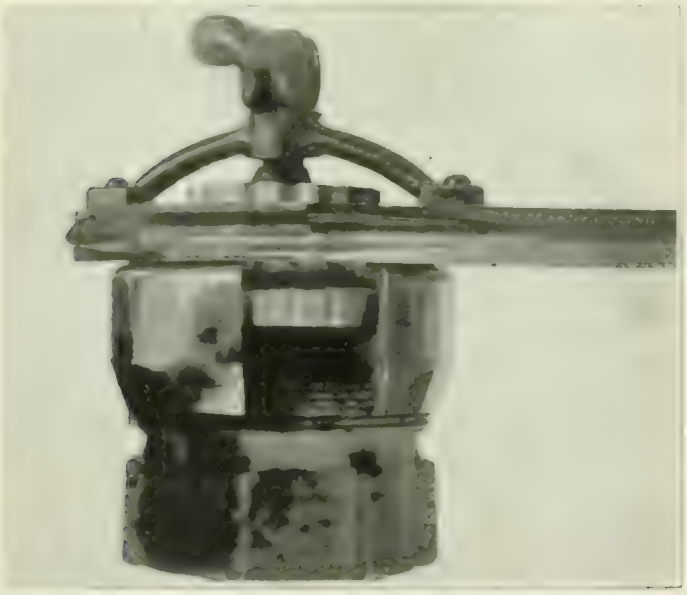
Wire wheels of the interchangeable type demountable at the hub are easier to remove, as all hub-caps are removable by unthreading them in the same direction as the wheels turn when the car is going forward, irrespective of the side of car, whether right or left. To insure the self-tightening effect of the hub-cap on the inner hub, we cut right-hand threads on hubs for the left side of car and left-hand threads for the right side. Hubs in the pioneer days of the industry were not properly identified by the maker. To ascertain the direction of rotation of a gear or of a magneto, it is customary for the observer to face the rotating member and determine whether it rotates clockwise or counter-clockwise. Many believed, consequently, that the right or the left side of the car was determined by facing the radiator. But we have always considered that the right or the left side of the car should be determined when sitting in the driver's seat. We find, even today, that the average car-owner will install the hub-caps wrong; that is, he will put those intended for the right side on the left, and vice-versa, the result being that the hub-cap, owing to the outward pressure of the wheel and the reversed threads tends to loosen and the wheels may come off. To obviate this possibility, a self-locking latch has been provided to hold the hub-cap in place, even though it may have been installed improperly.

Triple-Spoke System

It is conceded that the triple-spoke wire wheel is the strongest for its weight, this having been proved by extreme tests in actual service and having been exem-

[illegible] accidents that took place near Buffalo some time ago on the New York Central tracks at about the same point. An automobile equipped with wood wheels was struck by a train traveling at the rate of 40 m.p.h. and was carried about 150 yd., every spoke of the wheels being completely demolished. About 2 weeks later, a second accident of the same kind occurred. This time the train was a Chicago Express, traveling about 60 m.p.h. and the automobile was equipped with wire wheels. Although this accident was more severe than the first one and the car was carried much farther, it was found that two of the wheels were in absolutely perfect condition, a third wheel had only a few broken spokes and could have been used without difficulty; and even the fourth wheel, which received the direct blow from the pilot-bar and was bent considerably out of shape, had more than one-half the spokes still intact.

An interesting feature in connection with their strength is that triple-spoke wire-wheels have been used exclusively for racing purposes, one of the principal reasons, other than the advantage due to quick change, being that they combine strength with lightness and assure safety; furthermore, all the world's records for speed and endurance have been established on cars equipped with wire wheels.



[illegible] Disk Wheel Showing Integral Hub Cap Construction of Two Piece Steel Material

Mileage, Tire Changes and Get-Away

There is no question that greater tire mileage is obtainable from a wire-wheel-equipped car, on account of the resiliency of the wheel, which assists the tire in absorbing road shocks; the metal spokes also radiate the heat generated by the friction of the tires on the road. That can easily be proved, for on a hot day after motoring, say, 30 or more miles, you will find that the tires are barely warmer than the temperature of the air, whereas with wood wheels, as the spokes are non-conductors of heat, the tires are so hot they cannot be touched; and this heat certainly has a detrimental effect on the life of the rubber. Tests have proved that wire wheels effect a saving in tires of from 25 to 40 per cent.

Quick tire-change is very important as, generally, this is necessary at a most inopportune moment and may interfere with an appointment or with catching a train. The ease with which a tire-change is made is one of the outstanding features of a wire wheel demountable at the hub. All world's records in this respect have been made with wire wheels. At the Indianapolis races, on Decoration Day, 1922, Jimmy Murphy changed all four wheels in the remarkable time of 2 min. Later in the race, as a precaution against tire trouble, he changed his two right-side wheels in 8 sec., establishing a world's record.

It is conceded that a car equipped with wire wheels has a quicker get-away on account of the reduction of peripheral weight of the wheels. The weight of a wire wheel is at the hub, not at the rim, which makes the amount of material that is necessary to set in motion less and, therefore, makes it easier to start and stop the car.

With wire wheels, the weight of the car is hung or suspended; whereas, with wood wheels, it rests on one or two spokes that are in direct contact with the ground. This has particular significance when a wheel strikes against a curb, as one or two spokes may be broken in a wire wheel and the wheel still be in a serviceable condition, while other types would be injured beyond the possibility of use for continuing a trip.

Triple-spoke lacing forms a symmetrical wheel and comprises three distinct sets of spokes, the first extending from the outer end of the hub to the rim; the second, from the inner end of the hub at considerable inclination in the opposite direction to the first set and to the outer half of the rim to pull the rim inward and to counterbalance the pull of the first set; the third, from the inner end of the hub to the inner half of the rim so as to make the wheel rigid. The second and third sets do the driving and the braking, while the first set resists lateral strains from the outside. Any tendency of the rim to tilt in any direction whatsoever will be resisted by certain spokes acting longitudinally in the direction of their greatest strength.

Driving Parts

The earliest types of wire wheels were driven by six or more studs mounted in a hub flange, which corresponded to an equal number of holes in the hub shell and allowed the demounting of the wheel. Several designs of hub shell were made, the type now largely in use having the thickness of the hub-shell metal, plus bosses, pressed up when punching holes for drive studs.

An improvement in the method of driving has been brought out and thoroughly tested and is now in use in wheels of the latest type. This drive, known as a corrugated taper drive, consists of a driving flange on the hub with 18 corrugations on a 20-deg. taper. Corresponding to the taper on the hub flange is a taper on the hub-cap. When this has been screwed into place, it draws the wheel up on the driving flange and seats it on the corrugations, thereby wedging the wheel between the two tapered surfaces and eliminating the possibility of wear when the hub-cap is seated properly. The drive in the wheel itself consists of a separate tapered corrugated ring fitting similar corrugations on the driving member. The ring is a steel stamping pressed into the hub shell, which is crimped or pressed over the driving ring to hold it in place, the spokes being laced through both the inner driving-ring and the outer hub-shell.

It is interesting to note that the corrugated taper surfaces on the hub driving-flange are machined to a

(*Concluded on p.* 283)

A Critical Study of Modern Automotive-Vehicle Steering-Systems

By Herbert Chase[1]

Annual Meeting Paper *Illustrated with* Drawings

IN this paper the matter of locating steering drag-links received considerable attention and this question was also dwelt upon by several of the speakers participating in the discussion following its presentation. For that reason the following contribution by A. W. Werner, chief engineer, Parker Motor Truck Co., Milwaukee, is thought to be of value to engineers who wish to approach the theoretically perfect location of the drag-link. Inasmuch as it is so closely related to Mr. Chase's paper, it has been deemed advisable to print the contribution, which appears below substantially in full, as a contributed discussion of the paper rather than as a separate article. A brief abstract of the paper precedes the discussion together with a reference to the issue of The Journal in which the paper and the discussion following its presentation were published so that members who desire to refer to the complete text and the illustrations published in connection therewith can do so with a minimum of effort.

ABSTRACT

STATING that automotive literature presents surprisingly little helpful information concerning the faults of the steering-systems used on automotive vehicles and that, in spite of the fact that so many of the faults are self-evident, they frequently are overlooked in actual practice, the author includes with the presentation of his own investigations summaries of the views expressed by numerous well qualified automotive engineers and discusses these steering-gear faults in some detail.

Beginning with the subject of safety, consideration is given successively to the causes of hard steering, the angular position of knuckle-pivots, knuckle-pivot location, the foregather or toe-in of wheels, castering or trailing effect, wheel-wabble, drag-link location, irreversibility, steering-gear type comparisons, tie-rods and tie-rod arms. Numerous drawings illustrative of present-day practice are presented and commented upon, reference being made also to other articles, printed previously, that are pertinent.—[Published in the April, 1923, issue of The Journal.]

THE DISCUSSION

A. W. Werner:—In introducing a new method of layout we shall consider the location of the drag-link, since this member is the point of interest and if incorrectly placed will cause as much trouble as any other item in the entire system. Contrary to the universally accepted rule that the position of the drag-link should be such that its center line will intersect the center of the front spring eye, it is a scientific fact that the location of the drag-link depends entirely upon the characteristics of the front-spring design.

Before making a new layout the position of the steering-gear must be assumed and the design of the front spring must also be complete. Next consider the caster of the front axle. This should be made so that the angle from the vertical is the same as the angle of the spindle from the horizontal. On the majority of axles this amounts to from 1¾ to 2 deg. In the layout the spring is always shown in the loaded position.

The next step is to analyze the characteristics of the front spring to determine the exact location of the center of the ball of the steering-arm ball-stud attached to the axle under various positions of the spring. First, it is necessary to determine length l, Fig. 34, when the spring is in its normal rated load position. This length is found by the following formula:

$$1/2L = \sqrt{[(1/2c)^2 + (4/3h)^2]} \qquad (1)$$

where

c = Rated chord length
h = Height from center of the eyes to the top of the spring
L = Length from center to center of the eyes on the arc

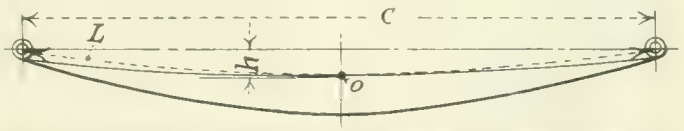


Fig. 34—Diagram Illustrating the Method of Determining the Approximate Developed Length of the Front Spring

From this we can proceed to lay out different positions of the spring, preferably five, two above and two below the normal position, by finding the length c for a predetermined height h. The two positions above and two below the normal position are best considered in steps 1 1-8 in. apart.

To find the length of c for any selected height h, we solve the equation

$$1/2c = \sqrt{[(1/2L^2 - (4/3h)^2]} \qquad (2)$$

Laying out these lengths indicating point o, together with their respective heights, in their natural shackled positions, it will be seen that they follow very closely a true curve, the radius of which is determined by equation (3)

$$R = [(1\ 2c)^2 - h^2]\ 2h_1 \qquad (3)$$

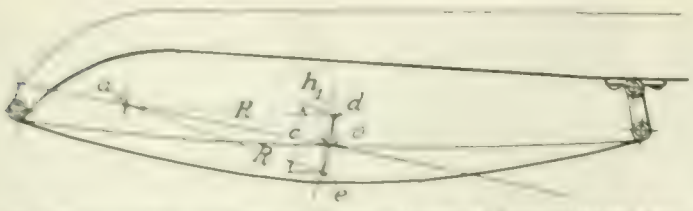
where

c = Chord length
h_1 = Height from chord line to top of the arc

These positions should appear as shown in Fig. 35.

Intersecting points d-e with the radius at the point a results in determining the exact fulcrum-point o of the spring. Knowing this position, it is necessary to consider only the distance relation x of the center of the ball on the steering-arm ball-stud and point o on the spring, and move the point f to point q a like distance so that it will represent the true fulcrum-point of the ball-stud center as shown in Fig. 36. With the spring in its

[1] M.S.A.E.—Engineering editor, *Automotive Industries*, New York City.



[illegible] ball-stud center and let it intersect the center [illegible] steering-gear-arm center-line at *y*.

This concludes the amount of work necessary to determine the correct position of the drag-link in the layout of the steering system. The length of the steering-gear arm can be made in accordance with the designer's wishes with relation to gear-ratio, and the like, but the ball-stud center must be at point *y* to secure the desired results.

It can be clearly seen that with such a method of layout the arcs of the front axle and of the drag-link are tangent at the point where the *position is most frequent* and that any deviation from this point, regardless of direction, is only slight. In all cases the distance traveled by the point in question results in a very slight tendency to lengthen the centers of the drag-link, which is allowable, since the position of the springs back of the sockets is favorable to this condition.

The condition is improved somewhat by an increase of the distance between the centers of the link. A longer link will remain tangent to the axle arc over a greater distance than will a short one. It is also apparent that no "push" or shortening of the drag-link centers that would tend to deliver a shock to the steering-gear because of the lack of springiness of the link in this direction is introduced.

It would certainly be amiss if we should overlook at this point the usefulness of the method described herein as applied to the brake connections. The entire method, including the consideration of the characteristics of the rear spring design, is applicable to the brake connections that are attached directly to the rear axle of a vehicle. It might be said that in a design employing the Hotchkiss drive this system is almost indispensable, in that we are able to determine the exact fulcrum-point of the axle, also of the eyes of the brake pull-rod levers. To be able to obtain brake connections that do not have a tendency to loosen or tighten the brakes when the axle changes its position means that we are assured of a constant and reliable braking system.

Similar to the consideration given to the drag-link, it is necessary first to lay out several different positions of the spring above and below its normal position, preferably three of each in the case of the rear spring, by the use of formulas (1) and (2). After plotting the point *o*, which represents a point on the top surface of the spring at its center line, we can again use formula

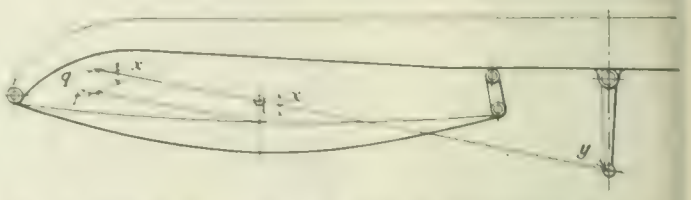


FIG. 36. METHOD OF LOCATING THE END OF THE STEERING-GEAR ARM TO MINIMIZE WHEEL-WABBLE

(3) for obtaining the fulcrum-point. The distance relation between point *o* and the eye of the brake lever should then be laid out with the same distance relation from the fulcrum-point. This, then, represents the true point of the radius of the eye of the brake lever and the distance between the eye and the fulcrum-point automatically represents the length of the brake pull-rod.

It will be noticed that in a layout of this kind the pull-rod is very much shorter than is usual in vehicles employing the Hotchkiss drive. Nevertheless the layout is absolutely correct and if put to a test will be found to work perfectly. It has been my experience that with this system of brake layout it is unnecessary to employ equalizers. This is due to the fact that regardless of whether one wheel is raised or lowered the fulcrum-point of the brake connections will remain fixed, and since there is no motion at this point there will be no necessity for providing flexibility.

TO INCREASE SAFETY OF HIGHWAY TRAFFIC

SAFETY on the highway is a matter of national concern. [illegible] during this last year 14,000 lives have been sacrificed in [illegible]. They are now registered in the United States [illegible] motor vehicles. This year's increase to that number is estimated by manufacturers at 3,000,000. The risk to safety lies in the congestion of 90 per cent of [illegible] upon 10 per cent of our roads. This risk we must minimize. That it is at the present time fraught with an appalling loss of human life is evidenced by the casualties from automobile accidents, a loss yearly which is greater than by all other means of transportation combined.

The majority of these accidents of congestion occur under five conditions, all of which road builders may help to eliminate.

(1) Sight distance on curves, both horizontal and vertical, which is insufficient to permit precaution against the many men's reckless driving. Lack of sight distance also increases accidents at intersecting roads and railroad crossings.

(2) Inadequate width of pavement, especially in congested districts, which increases the number of cars that turn over on soft shoulders and roll down unprotected slopes. Narrow or single-track bridges are a constant menace. In the design of roads 10 ft. should be allowed as a minimum width for each single line of traffic each way and 9 ft. more for each additional line each way.

(3) The inadequate, irregular and improper spacing of danger signs that encourages a general carelessness of their import. Judged by the number of accidents in their vicinity, they are a spur to the recklessness of the joy-rider and a consequent risk to his sober brethren.

(4) The tendency of detours under traffic to become almost impassable. On heavy-traveled routes traffic going in different directions should be routed over different detours, or, if detours are inadvisable on account of dangerous or impassable conditions, the road should be built horizontally a half at a time.

(4) Railroad grade crossings.—Extract from a committee report to National Highway Traffic Association

Comparative Merits of Steel Disc and Wood Wheels for Automobiles

By J. W. White[1]

Buffalo Section Paper *Illustrated with* Drawings

DISC wheels are the answer to a demand for something better at a more reasonable price. The art of making wood wheels has been established, the machinery has become standardized and further reduction in cost is improbable; whereas, the cost of suitable wood is steadily advancing and the trend, consequently, is upward. When the wire wheel was first introduced its use was a mark of distinction and to it can be traced the origin of the sport model, but its price cannot be reduced and it cannot compete, therefore, with the disc wheel on a price basis. The development of the disc wheel brought an equal distinctiveness of design and of pleasing appearance, but its progress has been different. The initial expenditure involved in the production of disc wheels is large; but the output also is large, and, as the volume increases, the prices become lower. The difference in the cost of painting is another item in favor of the disc wheel over both its competitors, even when the same number of coats are applied, but if high-bake enamel is used a surprising saving can be effected.

Two objections at first arose because of its demountable features: the first, because special carriers were required when the demountable-at-hub type was used; the second, because the demountable-at-rim type made it necessary to get under the car to adjust the brakes. Local conditions produce differences of opinion, wood and wire wheels being preferred in certain sections during wet periods because of the greater facility of handling the wheels by taking hold of the spokes. One of the most serious objections has been due to the trouble experienced in inflating the tires. Efforts to conform to the standards of other wheels brought complications in the use of the valves, so that it has become evident that, to secure the best results, steel wheels must be built around standards of their own.

It is possible to design a disc wheel with a lateral resiliency greater than that of any other type. This is particularly noticeable in turning corners, as it affords material relief to the tires. The tapering of the disc wheel toward the rim causes it to take a deflection readily at the rim but resists it in an increasing ratio as the deflection increases; it thus withstands impacts such as those against a curb that would cause a wood wheel to crack. Much must yet be done with the design to bring disc wheels into common usage, the features that require special study from a technical standpoint being strength, resiliency, fatigue, weight, noise and appearance. An advantage in weight formerly lay in favor of the wood wheel but this condition no longer exists, the disc wheel weighing slightly less in the 32 x 4 in. and the larger sizes. The difference in the energy consumed in accelerating the wood and the disc wheels has been found to be less than 0.01 per cent, which is less than the loss of energy due to windage in accelerating a non-skid tire as compared with that of a smooth tire under the same conditions. Reverse curves and crimps in the disc not only increase the rigidity but tend to restrict the amplification of sound vibrations. The difficulties attendant upon the securing of steel of sufficient and uniform hardness seem to have found solutions in the heat-treating of the metal before or after drawing, or in the using of carbon-steel drawn hot and hardened in a die afterward. Both involve manufacturing difficulties but give a uniform product, and increased strength and a reduced weight.

VERY few developments in the commercial world are a direct advancement. In most cases, progress is traceable to a demand from the user for something better or for a more reasonable price and therefore, in general, the development or improvement of any article is the manufacturer's answer to the demand. The automotive wheel industry of today offers an excellent example of this truism, particularly with regard to disc wheels. The wood wheel needs no apology for its service past or present. In hot dry climates it is at a disadvantage when compared with metal wheels, but far and wide its operation has been satisfactory, while economically its position in the past has been secure. When the wire wheel was first introduced, its use was a mark of distinction on cars of the higher class and a period of natural competition between it and the wood wheel prevailed. Each is now conceded to have a field of application in which its use is desirable.

The development of the disc wheel brought out an equally distinctive design of pleasing appearance, but the effect was entirely different. The price of disc wheels in the early stages was as high as that of wire wheels and their general use was therefore limited. To these two types of the metal wheel, and to the wire wheel in particular, can be traced the origin of the sport model, the finish and appearance of an automobile wheel being one of the featured points in the construction of the car that attracts the public by its racy lines and pleasing colors. It is generally known that one of the most important elements in the cost of a manufactured article is labor. Little argument is necessary to convince the casual observer that the wire wheel has a relatively high direct labor cost in comparison with that of the wood wheel, and that the disc wheel by the same comparison costs much less, especially the single-disc type.

The equipment of presses and tools involved in the manufacture of disc wheels necessitates a large initial expenditure. Once this investment has been made, however, the output of a plant manufacturing disc wheels is greater for the same investment than one manufacturing wheels of any other type. A metal-stamping plant must have quantity production to compete in price but, when volume has been secured, the parts can be produced with a minimum of direct labor cost. A few companies have been able to secure a fairly satisfactory volume of disc-wheel business in the last year, and this has been immediately reflected in the lower prices of disc wheels; consequently, the demand has grown rapidly, and at present the disc wheel appears to be in popular favor.

[1] M.S.A.E.—Chief engineer, disc wheel division, Wire Wheel Corporation of America, Buffalo.

of the car. This has made it advisable for all steel wheels to be demountable at the hub, even though they are demountable at the rim as well, and this feature is becoming standard.

It would seem that the disc wheel of the future should be demountable at both the rim and the hub; at the rim, to conform with wood-wheel carriers, which are less expensive, and at the hub to allow brake adjustment and quick change. Engineers are about equally divided in their opinions as to the use of four or five-wheel equipment, and it is logical to believe that the general public has similar differences of opinion. It also has developed that certain localities favor one type or the other because of existing conditions. For instance, in wet weather, in localities where adobe soil is prevalent, the change of the rim is preferable to that of the disc because the disc wheel cannot be handled by the spokes as can the wire or wood wheel. On the other hand, the demountable-at-hub type is easier to change mechanically, especially if it is used with a single nut as is the wire wheel. Disc wheels can now be made doubly demountable and as light as the five-wheel type; and this allows the manufacturer to supply four, five or six-wheel equipment, as may be preferred by the customer.

Disc-Wheel-Tire Inflation

One of the most serious objections has been the trouble experienced in inflating the tire. Up to 2 years ago, it was general practice to use a standard air-valve that passed to the rear of the disc, making it necessary to get behind the wheel to inflate it. This was awkward, unsatisfactory and troublesome; consequently, the owner let the tires become soft before paying attention to them and damage to the tire carcass and the cutting down of the life of the tire were the results. This caused all kinds of complications, on account of the complaints of users to the service branches of the tire companies regarding tire mileage, and resulted in a demand that the tire be inflated from the face of the disc. The angle-valve was the answer, and it has been used rather extensively for this purpose with some success. The chief objection to the angle-valve, however, is in the service. All sorts of angle-valves have been placed on the market. Patent extensions, rubber tubes and the like, have been supplied in an effort to overcome the objections, but the problem still exists. The stock carried by the tire companies at their branches and service-stations is equipped with standard valves. As different types of disc wheel have been adopted by various automobile companies, they have requested that the tire manufacturers furnish tires with the type of valve necessary for the type of disc in use by them, as shown in Fig. 1, and that the tire companies stock the various branches with tubes equipped with valves for those types. In a short time the tire companies were swamped with requests of this nature, and it became impossible from a financial standpoint for them to carry the burden of the increased inventory. As the car owner wears out his tires, he naturally buys new ones wherever he can, and takes the valve that comes with it. A number of wheel manufacturers have sought to overcome this objection by designing wheels that could use the standard straight valve now used with wood wheels. At first, it was thought impossible to do this without sacrificing strength and appearance, but good results are now being accomplished.

Disc and Wood-Wheel Comparisons

It will appear from the foregoing that, up to the present, the development of steel disc wheels has followed the

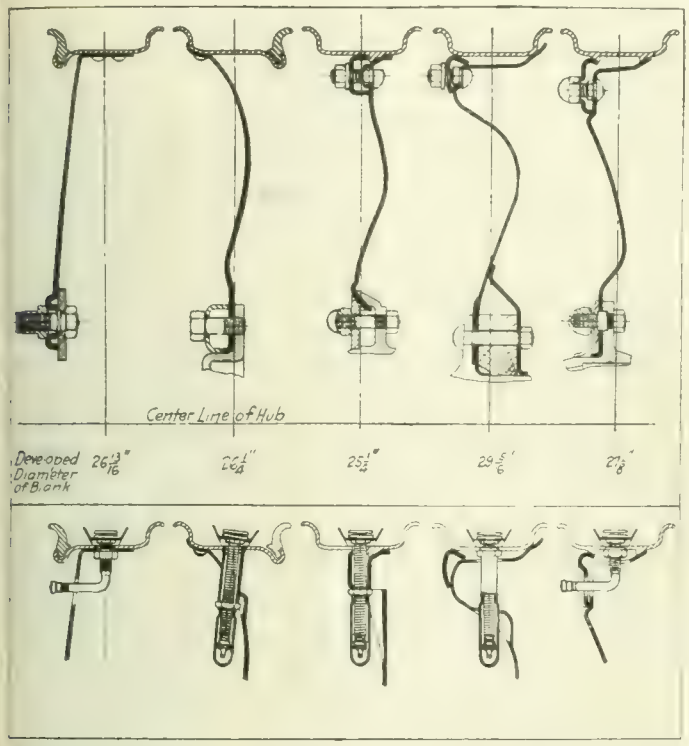


FIG. 1—TYPES OF DISC WHEEL AND THE VALVES USED WITH THEM

path of least resistance and that available standard parts have been used so far as possible. Upon careful analysis, it also appears that this has been responsible for most of the objections that have been directed against disc wheels. As their use increases, and more attention is paid to the fine points of their design, it is becoming more evident that to secure the best appearance, lightest weight, lowest cost and best operation, steel wheels must be built around a standard of their own. The rims that are used for wood wheels have been found too heavy and the locking-devices cumbersome. If disc wheels are substituted for wood wheels, the changes in design that would be warranted would modify axle design. For instance, with a single disc, the axle itself could be shortened by an amount equal to the difference in the widths of the wood wheel and the disc. The hub construction could be changed so that the bearing support in the semi-floating type of axle would be so close to the center of the wheel that it would become an almost universal type, making a substantial reduction in the cost of the axle itself and of the hub. If the four-wheel brake ever comes into general use on passenger cars, the use of steel disc wheels will follow, naturally.

Radially, the wood wheel has no resiliency at all; laterally, it has considerable, but this is restricted greatly by the rigidity of the felloe, the felloe-band and the rim, when they are clamped together as a unit. Any side pressure, therefore, is transmitted through the spokes in the lower half of the wheel in one direction and through the spokes in the upper half in the opposite direction, this movement being resisted by the diameter of the hub flange. In the disc wheel, a load-impact at any particular point causes the deflection of the rim at the point, as illustrated in Fig. 2, and the more the rim is deflected, the more the load is transferred by the rim round the wheel and absorbed. It is possible to design a disc wheel with a lateral resiliency greater than in any other type. This holds true only for the single-disc type or for composite designs that embody the same characteristics. To get extreme lateral resiliency in the disc wheel, the resistance to deflection must build up rapidly, as deflection is caused by impact. This is particularly noticeable in turning corners, as it affords material relief to the tires, the strain being absorbed more in the disc itself and the rim with a substantial reduction in skidding. The more rigid the wheel is laterally, the greater will be the shock that the tire must absorb; consequently, the tire will skid or transfer shock strains to the axle.

Another condition observed in wood wheels is the cracking at the hub that is caused by a sudden impact against a curb or other obstruction. The reason is that the spokes are not tapered toward the rim, because a large diameter is necessary at the rim to provide for a tenon and also to carry the load at the rim. If this were not necessary, the spokes could be tapered and the wheel would be fairly flexible laterally at the rim. Because of this rigidity at the rim and the inability of the spokes to flex as wood naturally does, the impact is sudden and localizes the strain at the weakest point in the spokes, which is also the point of greatest leverage. This condition does not exist in a disc wheel because, by tapering the disc toward the rim, or by securing the same result by the shape of the disc from the hub to the rim, the rim takes a deflection very readily but resists deflection in an increasing ratio as the deflection increases, similarly to the spring action on the car itself. This, together with the toughness of the steel-disc wheel, prevents the wheel from collapsing under the conditions mentioned above. Even though the blow may be sufficient to give it a permanent set, the shock is cushioned to save the axle; and the driver can get home. Much must yet be done with the design of disc wheels to bring them into common usage but, from the standpoint of design, none of the obstacles that have yet been encountered indicates that there is anything which will prevent them from becoming practicable from a cost or an operating standpoint.

ESSENTIAL TECHNICAL FEATURES

The essential features of the disc wheel that require careful study from a technical standpoint are: strength,

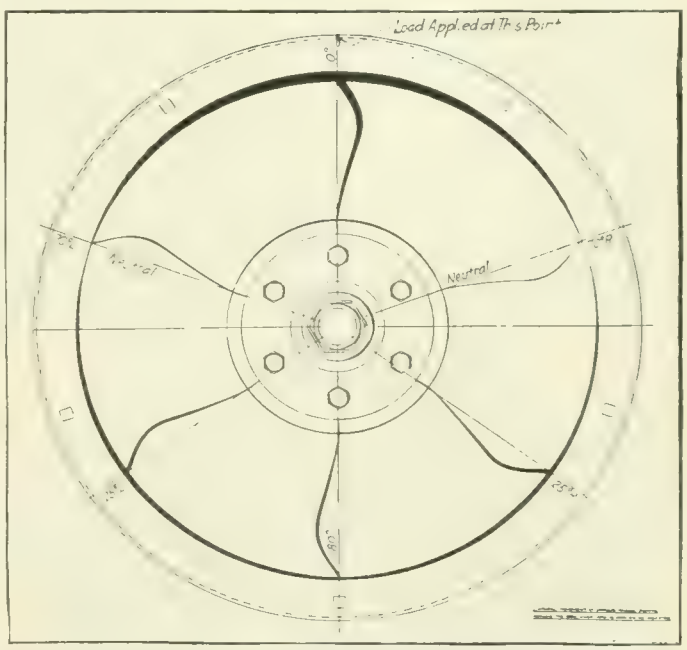
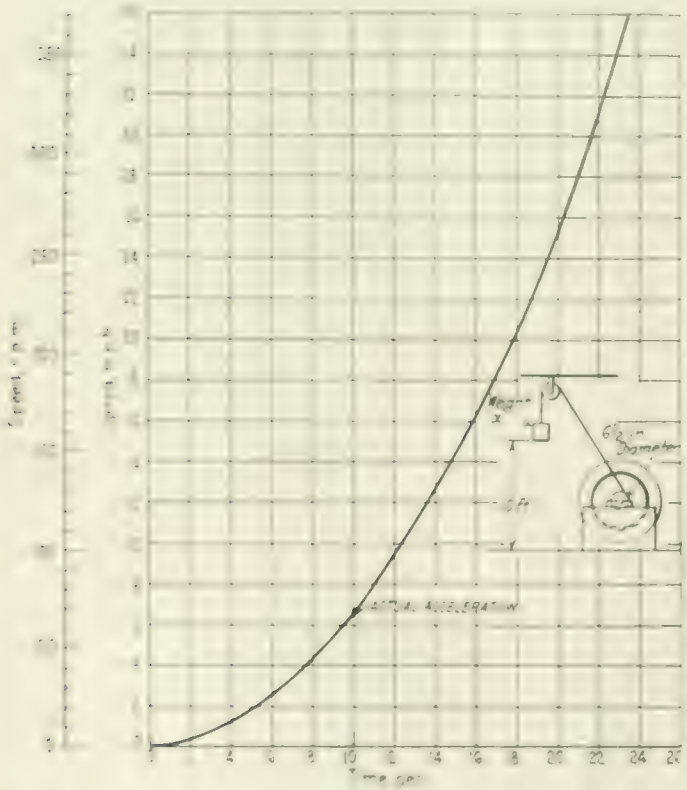


FIG. 2—LATERAL MOVEMENT AT VARIOUS RADIAL POINTS AROUND THE CIRCUMFERENCE OF A DISC WHEEL WHEN THE LOAD IS APPLIED AT THE TOP



Resiliency and Fatigue

Resiliency in a wheel is secured by first getting the proper strength at the hub portion and weakening the disc outwardly in proportion to the strength required at each point. This will give the maximum resiliency for any particular design. The desirability of this feature is not appreciated fully. In the first place, the stiffer the disc is, the more quickly will the blow be transmitted throughout the car, with the consequent inconvenience to the passengers and excessive shock to the mechanism. On the other hand, the greater the lateral movement of a disc of the same strength is, the less will be the fatigue at the hub, because with greater movement the more uniform will be the transmission of the load through the rim to the disc. The greater the distortion at the rim is, the less will be the localizing of the stress on the hub.

Fatigue of the wheel usually is manifested at the hub and, generally, is caused by poor designing of the disc or by too soft steel. If the proper resiliency at the rim is secured, and the strength of the wheel builds-up in the proper proportion toward the hub, the movement diminishes in the reverse ratio, so that there will be practically no movement at the clamping flange. If the outer portion of the wheel is too rigid, fatigue at the hub will certainly occur, because of the movement at the hub flange. It will be seen from the foregoing, therefore, that a compromise must be effected between the strength and the resiliency to secure proper results; and the more carefully and correctly this is done, the more weight can be saved. It is apparent also that the higher the elastic-limit of the metal is, the greater the resiliency will be, the strength remaining constant.

Much has been said as regards the extra weight of the disc wheel over that of the wood wheel, but these conditions no longer exist. A well-designed disc wheel weighs slightly less than a wood wheel in the 32 x 4-in. size; in the larger sizes, the saving increases rapidly in favor of the disc wheel. In the 30 x 3½-in. size, there is still a slight saving in weight in favor of the wood wheel.

Energy for Acceleration

Considerable comment has been made as to the energy consumed in accelerating a steel wheel on account of its being heavier at the rim. I have made a number of careful tests as shown in Fig. 3, and find that the difference between the energy required to accelerate the heaviest disc wheel to a speed of 15 m.p.h. and that required for the wood wheel averages less than 0.01 per cent, assuming a 10-sec. period of acceleration in high gear, which is practically impossible to secure.

It has been found that the loss of energy due to windage in accelerating a non-skid tire as compared with that of a smooth tire under the same conditions is greater than the difference in the wheels themselves.

Noise

Noise in the wheel is of two kinds: (*a*) the reflected noise and vibration from chassis parts and (*b*) amplification of this noise because of the shape of the disc being like that of a bell or a sounding board. Broadly speaking, tapered discs generally accentuate the noise, because the discs are sensitive to vibrations of low periodicity. Reverse curves and crimps in the disc tend to break up the free motion of the disc and, therefore, not only increase rigidity, but restrict the amplification of the vibrations. A disc properly designed should be dead, practically, so far as vibration and sound are concerned and, accordingly, the disc wheel should be quieter than others,

because it blankets the noises that come from the chassis, at least so far as their effect on the passenger is concerned. It is well known that chassis noises are more apparent when the running-boards have been removed.

So far as appearance is concerned, "the least said the soonest mended." One thing, however, that can be said is that large plain surfaces do not set the car off; and the general inclination of the purchaser is toward a disc in which there is a certain natural grace and strength. There is probably no wheel on the market today that lends itself to various color schemes as does the disc, because its smooth surface gives a more intimate relation between the wheels and the trimming of the car. The fact that a car has disc wheels is one of the noticeable impressions that the observer first receives and, therefore, will always merit careful attention from the standpoints of color value and decorative effect.

Steel for Disc Wheels

One of the great problems in the manufacture of disc wheels is the securing of proper steel. The average disc is made of S. A. E. 1020 steel, either hot or cold-rolled; in either case they should be full-pickled and the surface should be as smooth as possible, because, if objectionable pits and tears are present, they must either be polished out or filled during the painting operation.

When the discs are to be enameled it is usual to call for full-pickled full-cold-rolled stock. In most cases this surface will give a good enamel finish without further preparation. It is necessary, of course, that care should be used in handling discs of this finish in large production. The polishing equipment and space saved is well worth extra cost of full-finish material. When discs are to be painted it has been usual to use hot-rolled stock, because small defects can be covered-up in filling coats, but the full-finish material is preferable on account of the labor saved in the rubbing and filler coats that are objectionable because they crack in service. The real problem, however, is to secure steel of sufficient and uniform hardness. It is difficult to control the temperature of the billet during the rolling operation, and the hardness varies greatly unless the sheets are reannealed. The hardness of a sheet and the carbon-content should be as high as can be drawn in the press without injury to the metal and, therefore, the more difficult the shape is to draw, the softer is the metal that is used. In fact, the secret of making disc wheels is to make a design that will not draw the metal more than is absolutely necessary; in other words, to make the shape so that the punch will lay the metal into the die, instead of drawing it, because a certain amount of thinning occurs in the average disc, usually at the hub flange, which is the fatigue-point in operation.

A Brinell hardness of 130 to 145 is satisfactory for average purposes. We should like to go much higher but, at present, this does not appear practicable on account of the wide range of hardness that the mills demand; that is, 50 points. A disc of 100 Brinell hardness under test has shown fatigue about three times as quickly as a disc of 145 Brinell, although the grain structure of the harder disc may not be as good. Fatigue usually occurs at the hub, and a harder metal makes a stiffer disc with less lateral movement under the same load; whereas, the softer disc may show better structure and ductility, but moves so much more that fatigue occurs earlier. It is manifestly impossible to manufacture discs with these wide variations in hardness, successfully.

The solutions that appear possible are to heat-treat the metal before or after drawing, or to use high-carbon steel drawn hot and hardened in a die afterward. Both these alternatives involve numerous manufacturing difficulties. On the other hand, either of these processes will give a uniform product, an increased strength and a reduced weight. The future of the disc wheel appears to depend on the commercial development of some process similar to those outlined above.

Finish

Few people seem to realize the relation between the finished surface of the metal and the life of the paint. On an automobile body we apply from 5 to 15 coats of rough-stuff and paint to build up a good surface, and the same method has been followed in finishing disc wheels. This is absolutely contrary to what should be done. A disc wheel is subject to severe vibrations and deflections in service. The heat from the brake-drum is sometimes transmitted to the rear wheels, consequently the same conditions that apply to the painting of the body do not apply to the wheels; in fact, the ultimate disc wheel will furnish the same relative resiliency to the movement of the car laterally that the springs do vertically.

Fillers and rough-stuff are notoriously short in oil, whereas the varnishes are long in oil. It is apparent, therefore, that a filler or a primer will not hold to the disc as well as paints and varnishes long in oil. The smoother the disc is, the less of the primer or the filler that will be necessary; in fact, the first coat that is applied to the disc should be an oil coat to afford a surface for the color coat. The number of coats should be reduced to at least four, namely: (*a*) an oil coat baked on, (*b*) a color primer long in oil, (*c*) a color varnish and (*d*) a finishing-varnish. I am assuming, of course, that the necessary rubbing will take place between the coats and that oil-rubbing and sanding will be used in place of water. I should like to see the day when we can dispense with the primer coat entirely and use nothing but oil and varnish. It is apparent that enameling is the ideal finish for disc wheels but, on account of the decorative value of color, paint will commonly be used as well, particularly for sport models.

What the future holds for the disc wheel is impossible to forecast at this time. It is a fact, nevertheless, that with the scarcity of good wood, automobile builders have been compelled to find substitutes, and today even closed bodies are being made of steel. Steel lends itself to more economical manufacture and larger quantity production. We believe, therefore, that wheels will follow the trend of the times and will eventually be made entirely of metal. The disc wheel, by design and construction, is suitable for large production and low manufacturing-cost; therefore, it should assume a prominent position in the wheel industry of the future.

THE DISCUSSION

H. T. Myers:—Looking at it from a sales angle, we are confronted occasionally with questions from prospective customers concerning the virtues of different types of disc wheel and the problem of trying to explain the difference between a convex and a concave wheel as to cleanliness, looks and durability, the advantage of a convex over a concave wheel as to its being more soundproof and things of that sort. My opinion is that the concave wheel is the better looking wheel but, some time ago, a representative of one of the companies maintained that a convex wheel was cleaner and stronger and that it would be the ultimate wheel; that the concave wheel was noisy

[illegible] made tests for wheel rumble.

J. W. WHITE:—Differences of opinion make a horse-race. I think, however, that Mr. Myers' statements can be questioned. Speaking of the wheel to which he refers, I think there is no doubt about its being an easy wheel to keep clean although the gutter between the disc and the rim edge of the rim collects dust, dirt and water. I assume that when Mr. Myers says that an extreme design will collect dust, he refers to a wheel that is dished deeply. So far as noise is concerned, I should like to take issue with Mr. Myers. If you put cramps in the surface of a disc wheel you naturally will reduce the noise. A tapered section represents the section of a bell more nearly.

E. T. MATHEWSON:—How does the wire wheel compare with the disc wheel and the wood wheel as to flexibility?

W. F. DAVISON:—The lateral resistance of a wire wheel is much greater than that of either a wood or a disc wheel on account of the number of spokes and their high lacing tension. A wire wheel is three to four times as strong as either a wood or a disc wheel under strains of this kind.

MR. WHITE:—I can amplify Mr. Davison's statement in this way: A wire wheel is assembled under tension; you cannot have lateral movement in a wire wheel until the load applied exceeds the lacing tension; you must overcome the tension of the wheel before you can get any movement.

A MEMBER:—Will the corrugated drive become loose under ordinary conditions?

MR. WHITE:—We ran the corrugated drive for 1,000,000 torque oscillations; with a 54,000-lb-in. torque on a 30 x 3½-in. disc. The wheel on an average car of this size will deliver a torque of about 5000 to 6000 lb-in. to the road before losing traction; so, this load represents 10 times the maximum driving effort. At the end of 5000 oscillations, it had a 0.005-in. movement and at the end of 1,000,000 oscillations did not appear to have any.

F. GORDON REID:—I think Mr. White has brought out the fact that, in general, the merits of disc wheels are argued without knowledge. The difference in the weight and in where the weight is placed on the wheel certainly has an effect on the acceleration of the car, but the fact that the difference in acceleration between a rib tread and a non-skid tire was more than the difference between the lightest and the heaviest wheel tested is very interesting. To my mind, it will develop eventually that every automobile disc-wheel will be a glorified brake-drum, because tire sections are becoming larger to make riding easier. The rim will go on the brake-drum and the wheel will have an 8-in. tire. We have found that too much movement causes crystallization; so, we tried to prevent movement. Practically every automobile wheel that goes out of commission does so because it skids. The wheel that takes the least permanent set after a skid, it seems to me, is the best wheel.

E. S. INGHAM:—I am not an engineer; I am a serviceman. We have made both kinds of disc wheel, the convex and the concave. The blow that a convex disc-wheel gets puts the steel under tension. When a concave disc-wheel gets a sufficiently hard blow, the wheel will buckle and turn inside out. Our service-station repairs a large number of wheels other than those of our own make, and we know this to be a fact. Our wheels do not turn inside out; that is one point in favor of the convex wheel. The disc always is under pressure and the side blow must overcome that pressure.

MR. WHITE:—Mr. Ingham is correct in his statement that the convex wheel does take a shock well. You will notice in our design, however, that we have one concave shape changing to a convex at the hub. The reason we use two curves is to take shocks in both directions.

MR. REID:—Why are the nuts on the right side of the wheel represented by Mr. Ingham made with a left-hand thread and vice versa.

MR. INGHAM:—The principle is similar to that used with the hub-cap, but different. It is for the purpose of keeping the nuts tight. In our design, we have a different action. The disc is mounted on the hub and touches the hub only at the outer edge. The weight of the disc is carried on the nuts. The steel, being channeled, has naturally a certain amount of give. It is a fact that there would be a tendency to loosen the nuts if they were reversed. The flexing action on the nuts will keep them tight.

Discussion of Papers at the Semi-Annual Meeting

THE discussion of the papers presented at the recent Semi-Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort. The paper by James J. Shanley on Automobile Head-Lamp Regulation is printed elsewhere in this issue.

SHOEING A CAR WITH LOW-PRESSURE AIR

BY J. E. HALE

THE author describes the results of a deliberate attempt to make motor vehicles ride on air that is at a low pressure, through the usage of an air-cushion tire having greater carcass flexibility than is usual and by enlarging the size of the tire section so as to provide a greater area of contact between the tire and the pavement. The goal tried for was to increase the area of contact sufficiently so that air pressures ranging from 20 to 35 lb. per sq. in. could be employed in actual practice.

Fundamental conditions are considered first, followed by statements as to what advantages the air-cushion tires containing air at low pressure give to a car. The effects on car operation are presented at some length, inclusive of considerations regarding car speed, steering ability, front-wheel shimmy, traction, braking control, blow-outs, side-sway and other factors of influence.

Durability and tire cost are treated in some detail, specific applications of air-cushion tires to automobiles are considered and a discussion of their desirability is invited. In conclusion, recommendations are made for a new tire-size nomenclature, in regard to oversizing and to tire-deflection limitation; and specific tire-size recommendations for air-cushion tires on stated makes of car are advocated in the Appendix and tabulated. Numerous illustrations and diagrams accompany the paper.—[Printed in the July, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN T. J. LITLE, JR.:—We have asked the members to write their questions on the cards that were distributed rather than to state their questions verbally, for two reasons. First, questions will occur to the members as the paper is being read and, if these are jotted down on a card, they will be better questions than would be put extemporaneously from the floor. Second, many of us have the habit of getting up to ask a question and then continuing with a sort of lecture of our own that becomes very much involved and takes too much time. In the Detroit Section meetings, we have had as many as 65 questions asked and answered by the author of the paper in a single evening. Not more than from 12 to 15 questions can be asked from the floor and answered by the author within that time. Incidentally, this method is a sample demonstration that can be followed out in the Section meetings throughout the Country. I will now read the questions and Mr. Hale will answer them, one at a time. I will not read the name of the questioner to avoid possible embarrassment to him.

QUESTION:—Is it possible that a 7-in. tire on a heavy car would, upon rounding a sharp curve at high speed, be rolled over to such an extent that its side-walls would make contact with the road?

JAMES E. HALE:—Not if there were sufficient air-pressure in the tire.

QUESTION:—Why call them "air-cushion tires" when we already have so much confusion in defining a cushion tire? Why not call them "super-pneumatic" tires?

MR. HALE:—The Nomenclature Division of the Society might do some good work on that. I think a certain company might object to that particular term.

QUESTION:—Do you think it possible to decrease the running clearance over the front and the rear axles with the use of large tires? What is the cost in comparison with that of ordinary pneumatic tires? What is the effect of scraping the air-cushion tire side-walls on the curbing?

MR. HALE:—I think the road clearance will have to be figured substantially the same as for the high-pressure pneumatic tires. The comparative cost is not available at present because we have not got into volume production, but I can state that the tires will not cost enough more to make any sales resistance against putting them on the market. The side-walls seem to resist curb-scraping very much better than do those of the high-pressure pneumatic tires.

QUESTION:—Have any tests been made to determine the running temperature of the air-cushion tires?

MR. HALE:—No, but the temperatures will be very low because the carcass has no body to hold the heat.

QUESTION:—What is the effect on the air-cushion tires when running in deep, narrow ruts in clay roads?

MR. HALE:—The effect is the same as when a 5-in. tire runs in a rut that is made by cars having smaller tires.

QUESTION:—How long does the tire inflation last?

MR. HALE:—The tube seems to hold the air considerably better than does the tube of the high-pressure tire, because of the lower air-pressure. I cannot say how much longer it holds the pressure.

CHAIRMAN LITLE:—Would the leakage naturally be more rapid at the higher pressure?

MR. HALE:—[illegible]

QUESTION:—With the improved performance of the air-cushion tire, would it be possible to use plain tread, or grooved tires instead of the non-skid types?

MR. HALE:—We are trying grooved treads now and their appearance looks promising; we have made these tires with that effect. However, we cannot say whether they will be entirely satisfactory for replacing the non-skid treads.

QUESTION:—What is the value of the air-cushion tires for bus work?

MR. HALE:—They are being tried, but we have not progressed far enough with our tests to have any definite information.

QUESTION:—How does the air-cushion tire compare with the high-pressure tire regarding resistance to puncture?

MR. HALE:—A car in our test fleet had one puncture in 7000 miles on taxicab work, one puncture in 3700 miles.

QUESTION:—Were the taxicab economy-tests run under the same weather conditions, so that the engines were operating under comparable temperature conditions?

MR. HALE:—The figures given are for cabs running side by side in April. The high-pressure tires did not run one month and the air-cushion tires the next, but during the same testing period.

QUESTION:—What is the intended shape of the felloe for these tires? Is it the intention to use more than one felloe for the different size tire-bases in line with the recent standardization made by some of the tire companies for truck sizes? This refers to the rim-mounting feature.

MR. HALE:—No work has been done on that thus far.

QUESTION:—How many air-cushion tires have been run to destruction and what is the average mileage?

MR. HALE:—I do not have that information with me. If the person who wrote the question will write me, I will be glad to give him a suitable answer.

QUESTION:—When using air-cushion tires, why are snubbers necessary, the term "snubbers" meaning any good shock-absorber to check the rebound of the springs?

MR. HALE:—Without snubbers, the rebound inherent in the springs is multiplied by the soft cushioning of the air; it simply produces an excessive rebound in going over long ups-and-downs in the road.

QUESTION:—What is the effect of deep ruts on the thin sidewall?

MR. HALE:—It is about the same as on the high-pressure removable tires. We have made no extensive tests on that, however.

CHAIRMAN LITLE:—I have been driving a car for many thousands of miles on air-cushion tires and my practice is to straddle the ruts in many cases. I find that I can go over the rough, broken-up ground more easily with the large tire than with the small size. Ordinarily, I do not ride in the ruts nearly as much as I would with an ordinary tire. Does Mr. Hale agree with that?

MR. HALE:—Yes.

QUESTION:—What is the effect on the road due to air-cushion tires throwing stones, gravel and dust by suction?

MR. HALE:—[illegible]

CHAIRMAN LITLE:—Did your ultra-rapid motion-picture show anything in this connection?

MR. HALE:—I [illegible]

QUESTION:—What will be the effect on tires, wheels and rims, if the average car-user neglects to maintain the proper air-pressure?

MR. HALE:—I do not know.

QUESTION:—What is the relative volume and the relative weight of air in high-pressure and in low-pressure tires, when applied to the same car?

MR. HALE:—We do not measure the volume and the weight of the air because I think they do not mean anything. However, I will be glad to procure those figures for whomever is interested.

QUESTION:—Is hardness of steering when about to park a car partly offset by the ability of the wheels to mount the curb?

MR. HALE:—It is expedient to climb the curb if it helps the car to get into postion, that is all.

CHAIRMAN LITLE:—I do that about half the time.

QUESTION:—What are the reasons for saying, for instance, a 7.30 instead of a 34 x 7-in. tire?

MR. HALE:—What is a 34 x 7-in. tire? I know of no tire that has a measurement of 34 in. and none that has a measurement of 7 in.; so why call it 34 x 7? My thought is that the logical thing to do is to name the tires by an actual measurement that we find on the tire. When I say a 7.30 tire, calipers will show that the sections actually measure 7.30 in. The reason I do not use the standing diameter is that it seems unnecessary; there is only one standing diameter for a 7.30 tire. So, why not have a short cut?

CHAIRMAN LITLE:—Something was said about hard steering. It may be up to the engineer or to the gear manufacturer to make a steering-gear that will steer more easily and overcome the slight objection that some one might have to these air-cushion tires.

F. F. CHANDLER:—The company I represent has felt for some time that the subject of easy steering has not been studied carefully enough. We are now engaging in an engineering study of the subject. Also, we have produced a gear that, in our opinion, will do much toward accomplishing the satisfactory handling of the air-cushion tires. The whole subject of steering is one that is mixed up with the air-cushion-tire business, with the front-wheel-axle design, the drag-link connections, the kind of bearings in the kingpins and many other matters. It is a joint subject that should be studied by all. We are preparing to work out the better steering of automobiles, either individually or, more properly, in conjunction with others.

CHARLES L. NEDOMA:—Our experience is not as lengthy as that of the company Mr. Hale represents, which has been using their air-cushion tires for a long time. Their car rides more comfortably; however, the liability to puncture appears to be greater. We have found that a little tack that usually would not damage the ordinary tire blows-out the air-cushion tire. We had about six punctures in 8500 miles. The steering, I would say, is more difficult than with the ordinary tire, and the car lacks stability at high speeds.

CHAIRMAN LITLE:—Do you believe that some work might be done on the steering-gear to improve these conditions?

MR. NEDOMA:—Yes.

ERNEST WOOLER:—To emphasize the statements in Mr. Hale's paper about the skidding possibilities, it was raining when I left Cleveland to drive here, using air-cushion tires. A friend of mine who used ordinary tires and usually is a fast driver could not keep up with me. He noticed the chuck-holes during the entire trip and I did not know there were any. Steering changes already have been made on the car I am driving, so that the car now steers as easily as any I ever drove. The dust-raising properties of the air-cushion tires are a great disadvantage and so is the stone-throwing on a gravel road. I know of no other disadvantages as yet.

PAUL W. LITCHFIELD[1]:—We have had considerable experience in the past 3 or 4 years with tires of large cross-section and lower air pressures. It is well known, I think, by everybody in the automobile and in the tire business that there has not been the sufficient cushioning by the use of pneumatic tires that there should have been. It has always been a question with the tire manufacturers of trying to get the automobile builders to put on tires of larger air-volume, so that they could use lower air-pressures. The 10-per cent oversize in tires was largely an effort to get a larger tire on the existing rims, a tire with a larger volume that required less pressure, because it was realized that there would be increased comfort and not necessarily an increased cost per mile. It is a question, I think, of how far it is necessary to go in this direction. The time has arrived in the development of cord tires, I believe, when tires of larger cross-section and lower air-pressures can be introduced with very little increase in the original cost of the tire equipment and probably at a decreased cost per mile. The question is not whether it is a good thing, but how far to go and where to standardize. In the proposed schedule the weights are kept down to a certain extent by using narrower rims than the present standard. We found in several instances in the past that we had to widen the rims to get the proper rim stability to prevent shimmying and side-sway. We originally put a 3½ and a 4-in. tire on the same size of rim, and we had to make a wider rim for the 4-in. tire. We had to do the same thing with the 4½ and 5-in. tires, reducing the 5-in. rim when it came to sizes over 5 in. to secure rim stability.

For good equipment, we feel that it is necessary to use a wider cross-section of rim than that recommended by Mr. Hale's paper, which does not mean much increase in the weight, necessarily. At present, we have 4-in. rims; for instance, when using a 3½-in. tire, the 4-in. rim could be lightened. The use of tires of larger diameter necessitates the use of smaller wheels; instead of having 23, 24 and 25-in. wheels we can use wheels of 20-in. diameter. Therefore, the section in the rim can be made lighter and we still have the same stiffness. Thus, weight can be saved in the design of the rims without getting the rims too narrow to give the proper stability. Shimmying and the difficulty in steering are increased by making the rim too narrow, because the tire balloons over the rim to a greater extent and we have, in some measure, the troubles that we have in steering a tire that is insufficiently inflated; whereas, if the rim were made wider, we would get better stability to make it steer more easily and also to be able to drive with much greater safety at a higher speed.

Some of the exhibition cars that are here have 7-in. tires on 4½-in. rims. We have a car here that has 5-in. rims and 6-in. tires, which we believe to be a better equipment. To get the excess of air volume and still lower pressures and to keep the cost down means making a thinner carcass. We must have a certain amount of body in that carcass to prevent punctures and bruises and the picking-up of glass. While thickness is not necessary to hold the pressure, we must have a certain thickness there to prevent undue cutting and destroying of the tire by obstructions on rough roads. The tires on this car were inflated to a pressure of about 26 or 28 lb. per sq. in. for a 6-in. tire, which is sufficient for a car of this particular type. We do not feel that it is necessary to go to a 7-in. tire and, to keep down the cost, get a still thinner tire and put it on a narrower rim that does not give the proper stability.

In regard to not providing for over-sizing, Mr. Hale states that he thinks the time has gone by when the car builder will not put on a large enough tire. The very fact that these balloon tires are necessary at all shows that they are not putting on large enough tires because, if they did, they already would have reached that stage before this. We think that there always will be, in competition at least, a tendency to put on as small a tire as will be guaranteed under ordinary circumstances to give satisfactory results. There always will be times, with different sizes and types of bodies and with poor road conditions, where cars must be equipped with a larger-size tire than constitutes the original equipment. We think that the rims on a car should be such that, in case a sedan body is put on or the car is used in rough country where the roads are not good, the owner will have a rim that will take a larger tire and still give him economical wear.

Mr. Hale speaks of a 7.30 size of the tire instead of a 34 x 7 in. So long as there are wheels of different diameters it will be necessary to put in an over-all diameter to distinguish one from the other. To say "7-in. tire" is supposed to mean 7 in. but, in tire design, it varies more or less. We will have to get a nomenclature for the sizes similar to that used now.

S. P. THATCHER[2]:—The balloon-tire problem is another very fine illustration of the fact that a pneumatic tire is a compromise of many desirable qualities. We can increase any one of these qualities, but only at the expense of all the others. I agree entirely with everything that Mr. Hale has brought out with respect to the very greatly improved cushioning, but my experience does not check with his on the subjects of power consumption, ease of steering and the puncture hazard. I believe that the motoring public is used to a certain standard so far as punctures are concerned. Anything that is done along the line of the balloon tire must be done with that in view. We cannot change to too thin a carcass and, on the other hand, if we thicken the carcass we must use higher inflation-pressures. I favor a middle course.

I have noticed that, so far as the difficulty of turning the car or the steering-wheel is concerned, there is not much difference in the heavier cars, but it usually happens that the wheel turns before the tire does. In other words, the flexibility of the tire carcass at the lower pressures permits the wheel and the rim to turn inside the tire. A certain "snapback" is evident after a corner is rounded, which might startle a driver who was not accustomed to it; it may be possible to overcome this, but I am not sure. So far as high-speed work is concerned, I am afraid of the large thin-section tire. I can take anybody out on the road and scare him to death at 60 m.p.h. I believe that the balloon-tire development is a good thing if it is not carried too far or pushed too rapidly.

W. H. ALLEN:—I drove here, 500 miles, on air-cushion tires and had a very comfortable ride. However, it seems to me that the tire is really a small part of the problem, and that the major development is for the automotive engineer, who must find out what this tire really contributes to a car and then get out of it what is there. We can experiment with tires but, without the cooperation of the automotive engineer, I think our chances of success are rather remote.

C. F. OFENSEND:—We have been conducting tests on certain sizes for some time. We feel that the narrow

[1] M.S.A.E.—Vice-President and factory manager, Goodyear Tire & Rubber Co., Akron, Ohio.

[2] M.S.A.E.—Technical assistant to the president, United States Rubber Co., New York City.

[illegible] proposed by some is unnecessarily, and favor having the base no wider than that of the present rims.

H. W. ALDEN:—The tire manufacturers have realized that some car producers have been over-sizing to the point where now possibly 2800 or 3000-lb. cars are using [illegible] tires. They are now permitting an air-pressure of 40, 45 and 50 lb. per sq. in., dependent upon the load. [illegible] Mr. Hide terms the high-pressure tires. We have already taken a step in the proper direction toward increasing the ease of riding on the old type of tire by reducing the air pressures in proportion to the load that they carry.

MR. HALSE:—I was aware of some of the things that might come up from other tire members of the organization. It is only natural that there should be a difference of opinion on anything new. I have stated what we found to be our experience and we have tried to convey the idea that this is the result of a very extensive investigation. I will let it stand at that. Sooner or later the matter will simmer down to something. Whatever is the right thing will manifest itself and we will all arrive there. If I have been wrong I will be only too glad to admit it, but I can say nothing further except that everybody must bear in mind that developments are very rapid in the tire industry. Therefore, although some of these things seem to be rather startling, it, nevertheless, would be well to give them a trial, because they may happen to be right.

MECHANICAL BRAKING ON FOUR WHEELS AS A PRESENT AUTOMOTIVE NECESSITY

BY ALVIN M. YOCOM

THE author states that, when used in conjunction with the braking effect of the engine, two-wheel brakes work well in retarding a car on long or heavy grades, but that, for emergency stops, which are by far the most frequent, two-wheel brakes do not give a driver the positive control of the vehicle and the sense of security that are imparted by the retarding effect of braking on four wheels. The mechanical four-wheel braking system manufactured by the company the author represents is described and illustrated, the claim being made that the front-wheel portion of the system can be connected and equalized with any of the present-day rear-axle or transmission brakes without discarding any of the rear-axle or transmission brake-material. The equalization of brakes is discussed in some detail, inclusive of foreign practice, and other features such as "fight" in the brake-pedal, the mounting of the steering-arms and the distribution of shoe pressure to prevent chattering and "grabbing" are considered.—[Printed in the July, 1923, issue of THE JOURNAL.]

THE RENAULT MECHANICAL FOUR-WHEEL BRAKING-SYSTEM

BY MARCEL GUILLELMON

THE high car-speed demanded by present-day drivers of automobiles is stated by the author as having necessitated braking systems that more adequately overcome the effects of such increased momentum than is possible with ordinary brakes applied only to the rear wheels. Since, at the time the brakes are applied, the greatest part of the weight of the car is thrown upon the front axle and the front wheels, he believes it imperative that brakes be applied also to the front wheels and demonstrates that this also prevents skidding as well as increasing the braking effect.

The four-wheel braking system of the Renault car is then illustrated and explained in detail, and the advantages of this servo-brake system in regard to braking power, smoothness of operation and adequate car control are set forth. [Printed in the July, 1923, issue of The Journal.]

THE DISCUSSION

CHAIRMAN H. W. ALDEN:—This meeting is in the nature of an open forum dealing with the subject of four-wheel brakes. The speakers who have addressed you were not invited here to expound any particular type of four-wheel brake. They are authorities, however, on representative types of four-wheel brake and can help in the general discussion of the subject. This is not to be used as a channel for any individual four-wheel-brake advocate to present his case for any [illegible] brake, but the subject of four-wheel brakes is such a live one that the views of these gentlemen are interesting, and the discussion from the floor that is to follow will be interesting also.

CHARLES L. SHEPPY:—Regarding the problems involved in the application of brakes to front wheels, the tests and the research work covering a considerable period of time show that the application of front-wheel brakes to the average car, *as of today*, cannot be considered safe. If the front-wheel brake has to be considered seriously for regular production, the following several items should have serious consideration in order that the application of front-wheel brakes will give additional safety to the vehicle and not prove a menace to the public. The most vital problems in the installation of front-wheel brakes are

(1) The front axle should be designed to withstand the torque due to front-wheel brakes

(2) Front springs should be of liberal width, should have an extra top leaf, should have a center bolt to dowel into the axle, should be well supplied with rebound clips, should have the smallest possible arch under load and preferably no arch under load

(3) Spring bolts, spring clips and shackles should be of liberal size and of first-class material

(4) The cross coupling steering-rod should be straight, if possible, and, where spring-backed ball sockets are used, they should have a very limited amount of travel, preferably none

(5) The steering-pivot axle should have liberal bearing surfaces and be of such design as to withstand the additional stresses imposed by the use of front-wheel brakes. The steering levers should be kept as straight as possible and be of liberal sections and first-class material

(6) Bearings of sufficient capacity should be selected. The additional stresses on the front steering axles require serious consideration as to the loads imposed on front-wheel bearings

(7) The steering-gear operation should not affect the operation of the brakes, and the operation of the brakes should not affect the steering-gear operation in any way

(8) Center-point steering is not essential in the application of front-wheel brakes, its only advantage being that there is less load on the cross coupling steering-rod

(9) Consideration should be given in regard to what interpretation the State authorities of the several States will place on four-wheel brakes as coming within the law of the States that require two independent and separate sets of brake

From the comparative figures given in Table 1 for two and four-wheel brakes, respectively, it is evident that the car of today, with only two brakes on the rear and with the front axle and the springs designed only to take care of the static loads, is not adapted to take care of the additional weight and torque imposed by the use of front-wheel brakes. The spring makers will no doubt experience some difficulty in developing a satisfactory spring that will take care of the additional weight and torque due to the use of front-wheel brakes and still maintain the desired easy riding qualities that are required today. It is understood that the stresses imposed on the front-axle and the springs, as a whole, can be kept below the comparative figures given by using less powerful brakes on the front wheels. It is felt that this is advisable.

The type of brake is a matter of choice; it can have external bands, internal bands or internal expanding shoes. The internal type with properly ribbed brake-drums gives a longer life to the brake linings because of the better heat-dissipation. External bands when used hard lose their clearance and drag due to the brake-drum expansion caused by the poor heat dissipation, because the band surrounds the drum and insulates or holds the heat in the drum. The internal brakeshoes should be made of aluminum, preferably, to help cancel the expansion of the drum. Proper care in the selection of the material is necessary, due to the extreme heat to which these parts are subjected. Temperatures of 600 deg. fahr. have been obtained in the shoes during the tests conducted. It is noted also that internal brakes do not squeal when applied, while, with external brakes, this is a general complaint. It is felt that four-wheel brakes, when properly designed with due consideration for a liberal safety factor, are a desirable addition; otherwise, they had best be left off.

H. M. CRANE:—As one of the members of the Council, I favored holding this session to bring out into the open the very difficult four-wheel-brake problem that was being urged upon many of our engineers and to discuss the difficulties of obtaining the results that are desirable if we are to secure improved stopping power on our cars.

It is my understanding that, at the Indianapolis race, the four-wheel brake was rather conspicuous by its absence. In the road races, however, its use has been practically universal. The reason, to me, is obvious. In the road races, the four-wheel brake is applied and used for the definite purpose of rapid retardation. The driver is willing to accept an increased weight and a poorer steering gear to get the increased retardation. In the Indianapolis race, there is no reason for sudden stopping during the actual running of the race, except in an emergency. When the driver simply had to consider emergency stops, he preferred to leave the extra trappings off and obtain the lighter axle and car weights and the better riding that came with a simple brake system.

I am glad that we have had a description of the application of the four-wheel brake to the larger cars, necessitating, as is apparent in European practice, the use of an auxiliary mechanism to apply the brake. The reasons for this were not explained, but they are extremely simple. If we start from the simplest form of brake, that is, the transmission brake, we have a single brake-band or two brakeshoes mounted directly on the power-plant with a short and simple linkage; there is no chance for spring in the linkage, and no necessity for equalizers. When we proceed to the rear-wheel brakes, we have double the number of bands or shoes, an increased amount of linkage and a certain amount of come-and-go in many designs, due to inaccurate connections as to the layout of the spring centers and the brake-operating centers, so that a certain amount of kick from the pedal is involved. We have the spring effects, possible lost motion and the fact that the brake-drums then are placed in a postion where they must be protected more or less against dirt and dust.

The next step is to brakes on the front wheels in addition. We again double the amount of brake-drums and

TABLE 1—TESTS OF STOPPING DISTANCES OF THREE DIFFERENT TYPES OF BRAKE APPLICATION

	Type of Brake		
	Rear, External-Band Brakes	Four Brakes, Internal Shoes	Four Brakes, External Bands
Total Weight of Cars, lb.	6,000	6,000	6,000
Total Surface of Brake-Lining, sq. in.	332.4	308.6	600.0
Weight per Square Inch of Lining, lb.	18.1	19.4	10.0
Stopping Distance, in Feet, at			
20 m.p.h.	35	23	15
30 m.p.h.	70	45	35
40 m.p.h.	113	74	60
50 m.p.h.	175	114	90

Comparative Figures Based Upon a Coefficient of Adhesion of 0.9

		Two Brakes	Four Brakes
Wheelbase, in.		138	138
Height of Center of Gravity from Ground, in.		36	36
Total Weight of Car, lb.		6,000	6,000
Weight on Rear Axle, Level Road	per cent	58.6	58.6
	lb.	3,500	3,500
Weight on Front Axle, Level Road	per cent	41.4	41.4
	lb.	2,500	2,500
Transfer of Weight, Wheels Locked by Brakes	per cent	14.0	23.6
	lb.	840	1,410
Transfer of Weight on Grades Expressed in Percentage of Road Length. On a Grade of, per cent,			
10	per cent	15.1	25.1
	lb.	906	1,500
20	per cent	16.6	27.1
	lb.	995	1,625
30	per cent	18.6	29.6
	lb.	1,115	1,775
Greatest Transfer of Weight from Rear to Front	per cent	18.6	29.6
	lb.	1,115	1,775
Weight Remaining on Rear Axle	per cent	40	29
	lb.	2,385	1,740
Maximum Torque Transmitted to Each Pivot Axle, lb.-in.		.....	31,000
Bending Moments, in.-lb.			
Vertical		.....	27,800
Horizontal		.....	25,000
Combined		.....	37,400

cat, used in city traffic and in heavy suburban traffic, was pulled down a year ago after having run 62,000 miles and the transmission brake-liners were not changed; it was not considered worth doing although the car was taken apart entirely. Mr. Masury had a car that was equipped with a transmission brake, an old experimental car; he pulled it down last winter and, believing that it would be necessary to replace the brake-liners, he ordered new ones and had them on the ground. When that car was pulled down, the brake-liners were not changed, although the car had been run more than 40,000 miles while in his possession and many thousands of miles before that. Along with this long life of the lining are the facts that it is very rarely necessary to adjust the brake and, because the brake is not connected to the road wheels, it is absolutely free from any pedal action on rough roads. It also is the only form of brake that approaches equalization. Mechanical equalization of brakes does not necessarily mean anything. When brake equalization is dependent upon toggle action, it is obvious that unless the angle of the toggle linkage is exactly the same in both sets of shoes, the variation in the shoe pressure will be very great between the two sides of the car. The factory can adjust brakes as carefully as is possible, but no one yet has been able to make brake-linings that wear uniformly on both sides. At the end of 6 months, one brake will be holding possibly 50 per cent more than the other one when an absolutely equal pressure is being applied to the mechanism. No one yet has been able to manufacture a brake-lining that has uniform coefficients of friction. We all know from practical experience that the condition of the brake-lining in a car varies greatly from day to day when driving; undoubtedly, it varies greatly from side to side of the car, depending upon the amount of road dust and oil that it has absorbed.

I wish to make a plea for not throwing away anything that we have today that pertains to the steering safety of an automobile for the sake of securing an increased stopping efficiency. In building one of our cars, 10 years ago, we had a reactionary owner; he was a man 70 years of age and he insisted on having cushions that were 18 in. high; he insisted also on having high backs, with the tops tilted-up instead of lying flat and other things that were then out-of-date about 5 years. He also insisted on having clincher tires at a time when everybody else was using the demountable rim. The result was that his car was safe to drive at practically any speed on almost any kind of road without shock absorbers. The front wheels hugged the ground closely and maintained the steering. Exactly the same model of car, equipped with demountable rims and weighing possibly 50 lb. more on the front axle, felt extremely unsafe on the parkway at the same speed that this first car was perfectly comfortable to drive. It was necessary to use damping devices to obtain equal confidence in steering.

Ultra-rapid motion-pictures show that the front wheels of a car actually leave the ground for long spaces. This action is bound to be increased greatly by every pound of weight that is put into the front axle for a given weight above the springs. From what Mr. Sheppy has said, it must be obvious that a very great increase of the front-axle weight will be required by front-wheel brakes if they are to be at all satisfactory or even safe to use. Another feature of the riding at the front end of a car is a periodic vibration that is produced by the throw of the axle mass, including the wheels and the knuckles, between the tire and the springs. There is a relatively heavy weight that is being tossed up-and-down, with a

spring below it and a spring above it. The greater the weight is, the worse this condition is. In shaft-driven cars, I think we have all noticed that, at times, the rear end of the car seems to get up in the air and float, on a washboard or cuppy road. At such a time, there is mighty little control of the car. If we have the same thing applied to the steering end of the car, we have no control of it at all.

I am not a pessimist about four-wheel brakes, but I do know that there are some very serious problems involved with their application on account of the public. I dislike to see the automotive industry rushed into their production before it has had ample time to work out all the problems and to make perfectly sure that, when the car having four-wheel brakes is put on the market, it is as nearly perfect as our present engineering skill permits.

PRESIDENT ALDEN:—Those of us who have studied this front-wheel brake proposition are not altogether sure that we know just yet what we do want. The company I am connected with has been working at it for some time. While we propose to build four-wheel brakes if the time comes when that is absolutely necessary, we intend to take all the time that is needed to get them right.

C. T. MYERS:—I agree entirely with Mr. Crane. On the one hand it seems that, with four wheels, we should use the available tire contact for braking, but it will be a long process before we can effect satisfactorily the compromises that will be necessary to adapt four-wheel brakes properly. The point brought out by Mr. Crane that good design is the acme of simplicity should never come off the wall of any drafting room.

W. P. KENNEDY:—We ought to follow the principles laid down by Mr. Crane in being cautious at first and progressing cautiously afterward. If four-wheel-brake mechanism were to be used entirely by skilled operators, there might be very little risk about it; but, considering it as a trade and a manufacturing development, I think we are courting much trouble from the operators' and service standpoint and considerable misplaced investment from the viewpoint of the manufacturer.

W. G. WALL:—It appears to me that the die already has been cast. Considering the number of cars that are now being equipped with four-wheel brakes, we will certainly have to make the best of the proposition as it is. I favor four-wheel brakes. When designed and equalized properly, they certainly are a wonderful addition to any car. I have been driving with four-wheel brakes for the last 2 or 3 years. The most important question is whether four-wheel brakes can be kept adjusted. We know we can equalize them and adjust them perfectly so that we get very fair results for a short length of time, but there are so many problems that enter into the perfect equalizing of the four-wheel brakes that any one of many different things can happen to those brakes which will prevent them from being perfectly equalized and adjusted. All those that I have seen that have run several months without any attention have a tendency to show-up very differently from ordinary brakes. The adjustment may have been perfect and the design may have been as good as we now know about but, after a few months' use, especially over tar roads, dirt roads and muddy roads, they do not act as well as the ordinary brake. When I say "act well," I do not mean that they do not stop the car, because they always stop the car better than two-wheel brakes.

In connection with the design of four-wheel brakes, there are several things that we all must think about. Are we making our front axles in the proper way for these brakes? In general, we have come to think of the ordinary I-beam section as being the final word on front axles, but it is possible that we may have to design our front-wheel axles to take-up entirely different strains from what they have been accustomed to, and that some other type of section may be preferable. Theoretically, the tubular section probably would answer better. The car equipped with four-wheel brakes, if they are designed simply, with the transmission brake for an emergency, makes a wonderful driving proposition, but I agree with President Alden and Mr. Crane that we still have much to learn, not only about the design but about the application and the maintenance of four-wheel brakes.

JOSEPH A. ANGLADA:—Mr. Wall has stated very clearly exactly what my ideas are on the subject.

DAVID BEECROFT:—There has been the suggestion of a feeling at this session that sales considerations will be the dominating and the determining factor in regard to four-wheel brakes. Here is an opportunity for the members of the Society to take a stand for what they believe is right. If, in the past, the sales end has dominated more than have the engineers, I think we are now at a time in the history of the automotive industry when the engineer has an opportunity to be the safety-valve in this braking situation. From the public's point of view, there is great magnetism in the name "four-wheel brakes," and a great desire on the part of the public for them. We should conserve the best interests of the industry. I have ridden considerably in cars equipped with different kinds of four-wheel brake, but they were all beautifully set-up by the factory people and kept so for demonstration purposes. If we could always depend upon that adjustment, well and good. This is a time when the engineer really can stand-up for what he thinks is right. If you, as engineers, feel that four-wheel brakes are not generally desirable, have the conscience and the backbone to tell those with whom you are working that the engineers are not ready to take this particular stand. It will be much better for the reputation of our industry.

ALBERT J. GIFFORD:—Is it a fact that fully half of the European continental firms offer four-wheel brakes as standard equipment? If so, what success is that policy having and why is it that we in the United States are slow to adopt four-wheel brakes when they have been adopted in such a large degree in Europe?

MARCEL GUILLELMON:—In France, most of the cars manufactured in production have four-wheel brakes. There being no speed limit, one naturally drives much faster in France than in the United States. But, although the public drives at high speed, it desires the safety afforded by the cars equipped with four-wheel brakes and demands them from the builders. Evidently it means a considerable expense to add brakes to the front wheels, and especially to add a servo-brake. In Paris, the authorities are now studying the possibility of obliging all the taxicabs to adopt front-wheel brakes. In 1922, the Renault Co. delivered about 4000 taxicabs and, most probably, will now be compelled to equip them with front-wheel brakes, which would involve a large amount of work due to the necessity of changing the front axles, the springs and the like. Of course, this is a great expense for the taxicab company, but nothing should be spared when the safety of the public is concerned. About 75 per cent of the cars of 10 hp. and up, manufactured in production in France, are equipped with four-wheel brakes. The cars built by Renault, Panhard, Chenard-Walker, De Dion and Delage have front-wheel brakes on all models of 10 hp. and up.

MR. LITCHFIELD:—I am a believer in four-wheel brakes from the standpoint of safety. I think they will be put on all cars sooner or later. However, the great fear of some of us is that we will be too precipitate and put them on before they are perfected. It is conceded that most of the automobile accidents are due to inefficient brakes, either the brakes are not adjusted properly or they are not adequate for the car. Four-wheel brakes certainly help that situation.

I do not agree with Mr. Crane when he says that four-wheel brakes cannot be applied without a servo attachment or some auxiliary attachment to build-up the power. If they are of the external type, I believe that four-wheel brakes are perfectly feasible and practicable without any form of servo attachment. From a rough estimate, it seems that it takes about three times as much effort to apply internal expanding types of brake as it does the external brake that is designed properly. If advantage is taken of the tightening effect of an external brake, it can be used with a four-wheel brake to very great advantage and will require very little pedal-pressure. I think it is merely a matter of brake design and hook-up. The trouble with most of the four-wheel brakes of today is improper equalization. We have examined all of the mechanical and the hydraulic types of brake and have tried them out pretty carefully. I believe that proper equalization is our great problem. I think that four-wheel brakes are coming.

L. H. POMEROY:—I call attention to the essential difference between the external contracting and the internal expanding brake of the shoe type. The external band-brake is a wrapping type of brake; whereas, the internal expanding-shoe type is analogous to a plate clutch where there is a direct pressure between the friction surfaces.

The calculations applying to an external wrapping-type brake are identical with those determining the frictional contact between a belt and a pulley. The relative tensions of the tight and the slack side of the belt are given by the formula

$$T = T_1 e^{f\alpha}$$

where

α = the angle of contact between the belt and the pulley

e = 2.7183

f = the coefficient of friction

T = the tension of the tight side

T_1 = the tension of the slack side

It will be seen readily that the coefficient of friction is an exponent in the above equation so that the variation in the belt tensions and therefore the driving capacity of the belt varies to a greater extent than that of the coefficient of friction itself. The result is that, in the average external band-brake construction, a variation in the coefficient of friction of from say 0.25 to 0.33, that is 33 per cent, produces a variation in braking effort of some 54 per cent.

So far as the internal expanding brake of the shoe type is perfectly rigid, so far is the braking power only directly proportional to variations in the coefficient of friction.

The trouble with an external brake seems to be that it is so difficult to design it so that it will always work, as it is easy to design it so that it will sometimes work. The internal expanding shoe type has, in some respects, more problems, but, with good design, it can be made very powerful indeed and even with poor design it functions to some extent, whereas it is by no means unknown for the external wrapping-type of brake not to function at all.

After studying the subject of the internal brake for many years, I feel convinced that the secret of the design lies in extreme rigidity. In fact, given a choice between a brake of large diameter that was not rigid and a brake of small diameter that was as rigid as possible, I would unhesitatingly choose the latter. In this respect, the advantages of aluminum are very manifest. One is enabled to put deep ribs around the brake-drum without involving serious weight; it may be remarked that deep ribs should be tied together by cross-ribs at intervals, so that the circumferential ribs shall not distort like a piece of paper being bent edgewise. With a cast-iron insert, a brake-drum can be produced that is light and rigid and possesses great power of heat dissipation. My experience with such drums during the past 3 years has been that the brake-linings have stood up for 55,000 odd miles and show remarkably little wear indeed, although used under the most severe conditions. The necessity for rigidity applies also to the brakeshoes, which should be made just as stiff as it is possible to make them. This stiffness can be obtained with very little increase in the weight.

It seems very doubtful whether a servo-brake mechanism is required except for the heaviest type of car. The brakes to which reference has been made herewith are operated by spiral cams, giving an approximate leverage of 250 to 1 between the pedal and the brakeshoes. A motion of 2 in. on the hand-lever or the brake pedal will lock the brakes completely. This result, of course, means careful workmanship, but it is easily obtained by a grinding operation on the brake-linings themselves when the rear axle is completely assembled.

FOUR-WHEEL BRAKES IN ENGLAND

So far as I am acquainted with the English four-wheel-brake situation, this differs only from that in America to the extent by which the English are following the French more closely. The participation of English racing cars in the races in France brings English engineers into contact with cars having front-wheel brakes. The lessons learned at a race always seem very much more emphatic than those that are learned by many times that amount of ordinary road work. In England there are certain companies that are fitting a front-wheel brake. Some are putting it on as an optional device and I think they are putting on a good many. The actual movement has not gone very far because the automobile industry in England has been very sadly crippled during the past several years. However, I have no doubt that the front-wheel brake will become just as popular in England as it will in the United States.

One finds, all through the United States, a movement from something that has been tolerated because there has not been time to change it to something that is the very best that possibly can be. I think the same thing will happen with the four-wheel brakes. I have yet to find any real American engineer who can champion the average American rear brake. The four-wheel brake that can be built in quantities and therefore built cheaply will remove possibly the last material criticism of the American car as it now stands. It seems to me that the position we must take as engineers is not whether we are to have four-wheel brakes or not, but that we will have them and that it is our business to get them as quickly as we can, consistent with the necessities of the case.

MR. LITCHFIELD:—The importance of the question of extra braking facilities increases as we go up to greater weights and higher speeds. It will be especially interesting in the field of passenger carrying, in trucks and buses and vehicles of that nature. I call special attention to the braking facilities on the truck designed by

the Army; it has four drive-wheels mounted on an oscillating truck and the four-wheel braking-system. The results obtained in braking heavy loads running at high speeds are remarkable.

C. M. MANLY:—The mere fact that the four-wheel brake problem is difficult is the very reason that all the more attention should be paid to it and that the work of its solution should be got under way as early as possible. The difficulties of the problem should not deter engineers from tackling it.

DAVID FERGUSSON:—I have read with much interest the recent papers and discussions on four-wheel brakes that have been presented before the Society, and I am rather surprised that the advocates of four-wheel brakes have not stated the obvious fact that four-wheel brakes do not increase the static load on the front axles and the front springs over the load imposed by rear-wheel brakes capable of locking the rear wheels, when the deceleration is the same in both cases. Also, in holding down the speed of the car on a hill of say 10-per cent grade to 15 m.p.h., the car with four-wheel brakes does not impose any greater static load on the front axle than does the car equipped with rear-wheel brakes, under the same conditions. Four-wheel brakes only impose a greater static load on the front axle when they are used to give a quicker deceleration than can be obtained with rear-wheel brakes.

I am inclined to think that four-wheel brakes capable of locking all wheels rarely will be used to stop a car in the least possible distance except to avoid a fatal accident, because such rapid deceleration, approximately double that of rear-wheel brakes only, is not only uncomfortable to the passengers but may actually injure them unless they are prepared for the stop and have something substantial to hold on to. A stop from a speed of 30 m.p.h. within 70 to 80 ft., which can be accomplished with a car fitted with rear-wheel brakes only, is as quick as should be indulged in under ordinary conditions unless the driver is alone in the car, since he has the steering-wheel to brace himself with. A deterrent to making a quicker stop of the average car than that is the danger of being run into by the car behind; this obtains in the majority of brake applications for city usage. The average driver of a car equipped with four-wheel brakes will not make quicker stops than he could make with a car having rear-wheel brakes only, in more than perhaps 5 per cent of the decelerations he effects. This indicates that the increased load upon the front axle is incurred very rarely.

I have driven cars equipped with four-wheel brakes that were capable of locking all wheels, making stops in the least distance possible without causing the front-spring bumpers with which the cars were equipped to strike the under frame violently, but these same cars would strike the bumpers most violently when run over a depression in the road at high speed, showing that the front-wheel brakes did not impose as great a static load on the front axle and its parts than already had to be provided for.

Most conditions in connection with the application of four-wheel brakes can be met very easily, though only by added complications. There are, however, some problems that present difficulties such as (*a*) the avoidance of locking the front wheels when making a turn with the brakes applied; (*b*) the maintaining of sufficient travel of the foot-brake lever after taking up the slack to leave still enough travel to apply the brakes properly after a little wear has taken place and (*c*) the provision of sufficient leverage to apply all four brakes fully, without undue effort, where no assistance from complicated servo attachments is used.

This problem is exceedingly great in the case of heavy cars as, with rear-wheel brakes only, it is difficult to provide sufficient leverage to lock the wheels easily and maintain sufficient travel for the brake-pedal. With the same leverage, double the pressure on the pedal will be necessary to lock the front and the rear wheels, and there will be double the slack to take up. This may result in the necessity for frequent brake adjustments, even though the additional front brakeshoe surfaces may give double the total area to that used in the case of rear-wheel brakes only. Additional problems are (*a*) the provision of a simple means of adjustment for wear on each brake-shoe that can be made quickly and easily by the average driver and (*b*) the maintenance at all times of proper equalization.

IMPORTANCE OF BETTER AUTOMOBILE HEAD-LAMPS AND PROPER ADJUSTMENT

BY R. N. FALGE AND W. C. BROWN

THE accurate construction and easy adjustability of automobile head-lamps, though they have received much attention, are still susceptible of further improvement. If motorists realized that the road would be illuminated better, objectionable glare could be avoided and a better and safer head-lamp would be secured by properly adjusting the head-lamps now in service, an immediate and far-reaching improvement would be effected.

Views are given of tests made with the common type of head-lamp with a parabolic reflector to show the effects produced by placing the source of light at the focal point, by moving it forward, backward, above and below this point, and also by cylindrical flutes in the glass and by horizontal prisms. The head-lamp is shown to be very sensitive inasmuch as the distances from the filament to the reflector are very short when compared with those to which the light is projected. A type of lens is described that will compensate for the commercial variations in the position of the filament and at the same time distribute the light effectively, converging or diverging the rays laterally while maintaining the top or cut-off substantially at the level of the head-lamp. As the maximum intensity should be placed as near to the top as possible to illuminate the road-bed most effectively, and as the eye accommodates itself slowly to changes of intensity, the lens takes advantage of these characteristics by spreading and bending the light in each zone by different amounts.

The requirements are given for the uniform and satisfactory service of lamps and of such parts as filaments, sockets, reflectors, lenses, doors and mountings, the underlying idea being the use of devices that will obviate the necessity for focusing and leave to the motorist only the simpler adjustment of aiming.—[Printed in the July, 1923, issue of THE JOURNAL.]

THE DISCUSSION

DR. C. H. SHARP:—The head-lamp situation is of vital importance to the automobile industry. If head-lamp conditions on the road are not improved, laws regulating

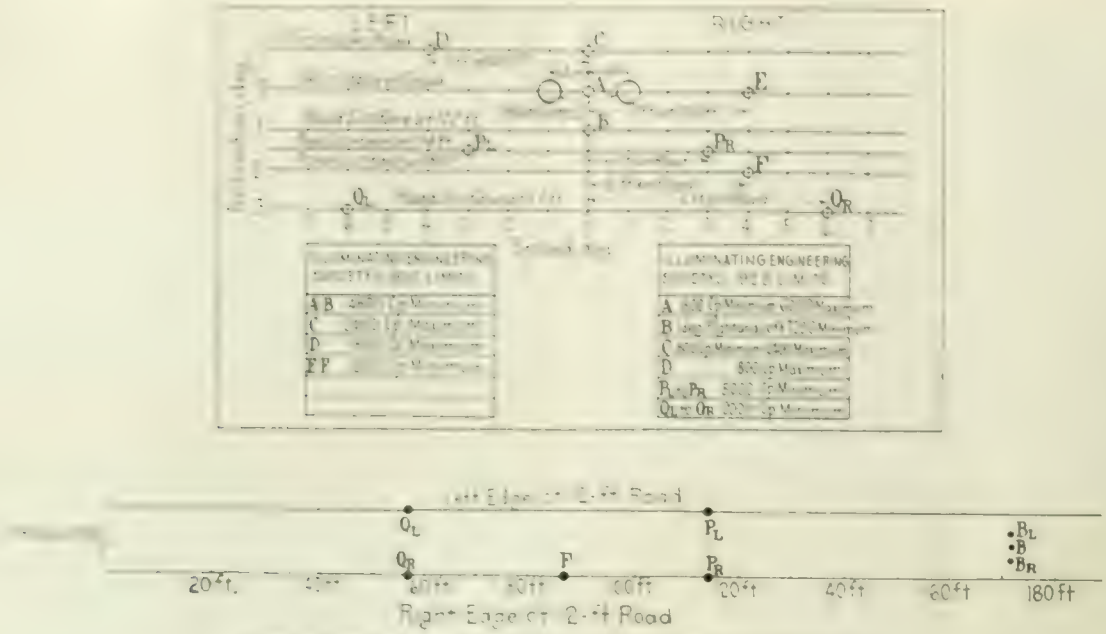


FIG. 1—BEAM LIMITS FOR THE LABORATORY TESTS OF HEAD-LAMPS

conditions are likely to become more drastic and the more chances there will be for trouble that will react directly upon the whole automotive industry. Much has been done in the guidance of legislation bearing upon this question. This has been done to a large extent jointly by the Lighting Division of the Standards Committee of the Society, working with the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society that took up the question about 6 years ago and has been working at it from the illuminating engineering point of view. The result of the work of these committees has been to formulate testing specifications for the approval of head-lamp devices and in putting such specifications before the State officials who have this regulation in hand, giving them thereby a rational means for going ahead with their regulatory functions. The diagram of approved practice in road illumination, Fig. 1 of Mr. Faige's paper, is very similar to the diagram that describes the official tests for approval of head-lamp devices to go on the road. This system of regulation has gone a long way in this Country. Many of the largest States have adopted it. Some of them, notably California, have incorporated it directly in their law. Others have taken it up through the operation of their administrative officials.

The most recent progress along these lines has been in the adoption of this system by the Conference of Motor-Vehicle Administrators of 11 of the Eastern States, covering New England, the Middle States and the State of Ohio. These administrators have determined among themselves that they will approve devices only after they have passed this standardized test which, by the way, has been adopted by the American Engineering Standards Committee as an American Engineering Standard. They will approve devices only after having passed this test, and then only after the device has been given a joint consideration by the administrators. When specifications of this kind were first brought out, they were made very lenient. It was a matter of common sense and good policy to do so. Since then, as a result of greater experience, they have been tightened-up and improved all along the line, and the latest form in which they exist and which has been approved by the American Engineering Standards Committee was adopted in 1922.

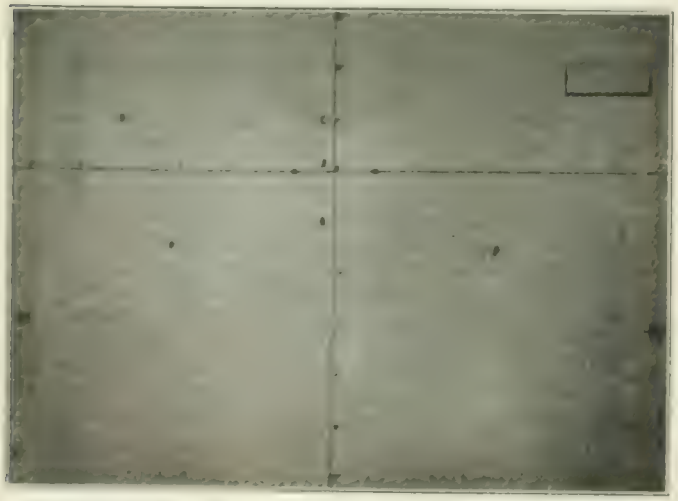


FIG. 2—[illegible]

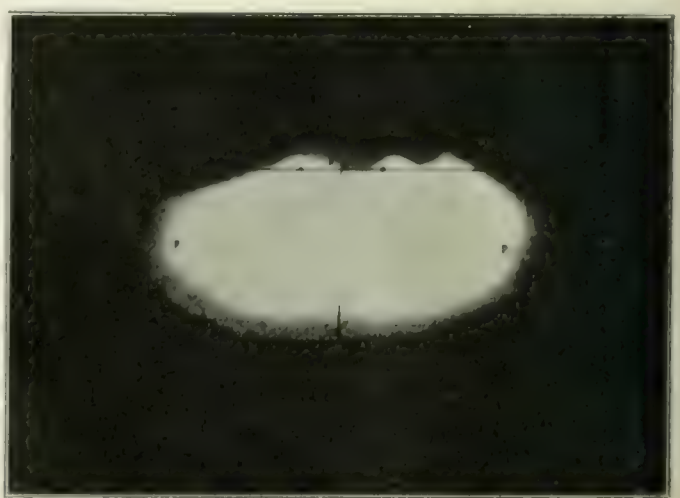


FIG. 3—THE EFFECT ON THE BEAM PATTERN OF COVERING THE UPPER HALF OF THE LENS AND PULLING THE LAMP BACK

Under the older specifications, many devices were approved by the States but, owing to the adoption of the later specification and to the consideration of the matter by the Committee of the Motor-Vehicle Administrators, a very large number have now been weeded out. Under the older standard, the beam had to be deflected downward, but there was no special requirement that the beam should be spread laterally. The later requirement has introduced this lateral spread.

The beam limits shown in Fig. 1 are those for the laboratory test for approval of types according to the standard specifications. Fig. 2 shows the beam pattern of a very well-known type of diffusing lens that was in use at the time the early specifications came out. Fortunately, this inefficient device falls far short of meeting the present specifications. Fig. 3 shows the effect of the covering-up of the upper half of the lens and pulling the

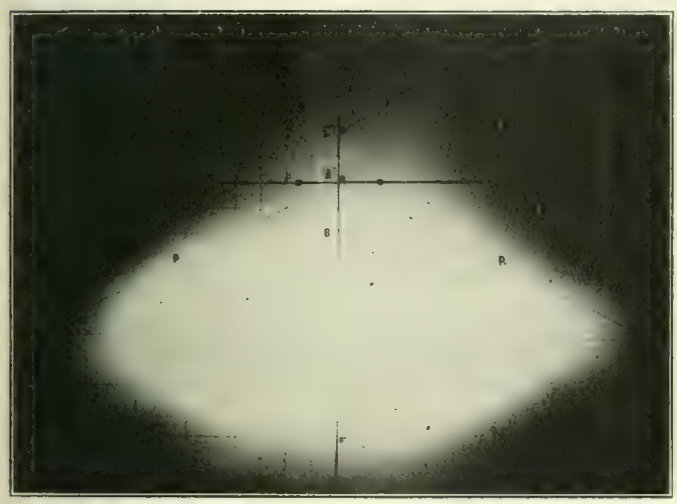


FIG. 4—THE BEAM PATTERN OF AN EARLY PRISMATIC LENS

lamp back. That produces a beam pattern which brings in the points R_l and P_r, but does not include these wider spread points of Q_l and Q_r. Fig. 4 shows the beam of one of the prismatic glasses of earlier days that is subject to the difficulty mentioned for Fig. 3. It is now obsolete. Fig. 4 shows that the lateral spread of the beam was not great and it threw a great amount of light near the car where it was ineffective and objectionable on account of glare.

Fig. 5 shows the beam of another device that might

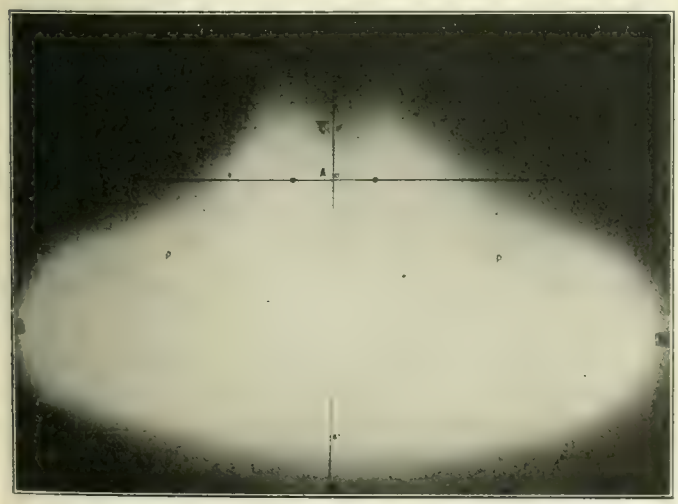


FIG. 5—THE BEAM PATTERN OF ANOTHER EARLY LENS

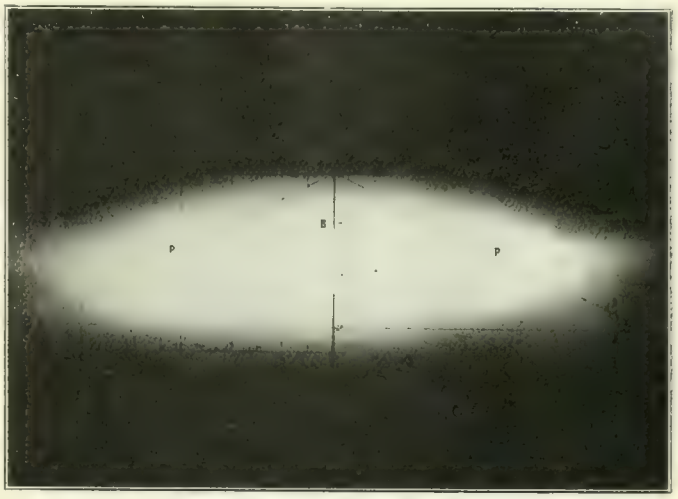


FIG. 6—DISTRIBUTION OF LIGHT FROM AN APPROVED HEAD-LAMP

come in, but that has been improved greatly since that time to bring it into accord with the modern requirements. Figs. 6, 7 and 8 show the beams of modern front glasses all of which are approved and are good, although they show definite individual differences. The "best" for any driver is the one that he himself prefers. Fig. 9 shows a beam that is cut-off very sharply above and below. This is open to certain objections in that it does not give enough light in its upper portion. It is not safe to have a device that has too sharp a cut-off. There must be some light up where the branches of the trees are, where the load of hay begins above the wagon wheels and in similar places.

FIG. 7—BEAM PATTERN OF A MODERN HEAD-LAMP

Table 2 gives a few figures on the results of testing operations for States under these various specifications. The figures given are taken from the records of one testing organization only. Table 2 shows that in 1918, under the several specifications for New York State, 86 devices were tested and 55 were approved; for Pennsylvania, 107 were tested and 80 approved; for Connecticut, 68 were tested and 52 approved. Then the specifications were made slightly more rigid. In 1920, for New York State, 28 more devices were tested and enough were approved to bring the number up to 92; for Pennsylvania, 8 more were tested and all were approved, making a total of 88; for Connecticut, 9 more were tested; Maryland shows 66 tested and 57 approved. Massachusetts had a slightly different specification. The authorities tested

[illegible] Approved Headlamp That Is Now on the Market

[illegible] were approved. Under the recent action of the Motor Vehicle Administrators working under the latest specifications, only 22 of the whole lot have been approved. Many of these earlier devices were never manufactured; they were impractical and useless. Others were subjected to some redesign that brought them under a new form number and thus brought them under approval; so, in Pennsylvania, the reduction from 98 to 22 does not represent a mortality of good things. Of all the [illegible] that ought to have died, a great many of them were already dead when this action was taken.

TABLE 2—RESULTS OF TESTING OPERATIONS

State	Specifications for 1918 Tested	1918 Approved	1920 Tested	1920 Approved	1922 Approved
New York	86	55	28	92	22
Pennsylvania	107	80	8	88	22
Connecticut	68	52	9	47	22
Maine and [illegible]	..	..	66	57	22
[illegible]		..	58	32	22

[illegible] the 1922 specification was [illegible]

[illegible] Standards Committee's Lighting Division and the committee of the Illuminating Engineering Society have done good work that has been accepted by the States. It is a national system for handling head-lamp

[illegible] Lamp in Which the Beam Is Practically Wholly Controlled by the Lens

devices, but the committees cannot do very much more. From now on it is a question of the enforcement of the law, of the education of the men who drive cars and the men who build cars. The work that the committee has started and brought a long way should now be taken up by the individual members of the Society. The system is not perfect but it is a good one and the members of the Society ought to try to get it going. The sooner a general observance of the questions of focusing and aiming of good head-lamp devices is obtained through the general enforcement of the law as it exists, the quicker the industry will be insured against some drastic action on the part of the State authorities.

The engineers connected with the manufacturing companies can do much by seeing that good head-lamp devices inclusive of front glasses, good reflectors, good sockets, lamps that are put together right, and lamp supports that will stay adjusted, are put on their cars. All of those details come right up to the manufacturing end. No one can take up the work of these committees and push it forward to a successful conclusion better than the engineers who are connected with the manufacturing companies throughout the Country.

CHAIRMAN B. B. BACHMAN:—One point brought out by Dr. Sharp is particularly pertinent in that all of us who are engaged in the construction of vehicles are vitally concerned with the matter of uniformity. The dissimilarity of regulation in the various States is the one thing that has given us much concern; certainly it is one reason why we should endorse and support an activity of this sort that is acceptable to the authorities. As engineers, we are concerned with the formulation of regulations of this sort.

ALFRED REEVES:—The manufacturers are keen for laws that will make for the safe use of motor cars on the highways, and they desire to equip their machines so that they will come within these laws. I have always had a very high opinion of Commissioner Dill, of New Jersey, and his fairness in dealing with these matters. However, I call Mr. Shanley's attention to the fact that materials for motor cars are purchased a long time ahead. Our legislative department endeavors to keep the manufacturers informed of proposed changes in legislation. Most of the laws passed allow a certain amount of time for changes to be made and that is just what we would like to have done in connection with the lighting equipment. We need time in which to decide what should be required of automobile lighting, and then the manufacturer should be allowed time in which to comply. Our great difficulty lies in the fact that what may be legal in one State is not legal in another. The recent offer of Commissioner Dill to secure some uniformity along these lines will have universal support. Ten States, I believe, are planning to cooperate with him in preparing proper legislation. If they will tell us their requirements, I can assure them of the finest kind of cooperation from the engineers and from the automotive industry.

A. D. T. LIBBY:—I have been on the Electrical Equipment Division of the Standards Committee for a number of years and have tried out a number of different head-lamp devices. I want to emphasize what Dr. Sharp and Mr. Shanley have said that this is a problem to which the engineers of the manufacturing companies should give consideration.

E. C. CRITTENDEN:—At the Bureau of Standards, we are asked repeatedly what the best head-lamp device is. We cannot answer that question because we do not know and could hardly publish the information even if we did know. It depends to a great extent upon one's

preference as to the distribution of light on the road. It also depends somewhat on the speed at which one drives. There is a widespread interest not merely to know what the best device is but in the possibility of devising a formula that can be used by the authorities everywhere. We have many such inquiries from State and city authorities who wish to put into effect some kind of regulation. Fortunately, we felt entirely justified in recommending these requirements concerning which Dr. Sharp has spoken. It is not generally known how much labor has been spent in devising these regulations. Engineers of the Society, as well as those in the Illuminating Engineering Society who were considering the matter, have spent many an evening on the roads, actually trying various devices to determine what limits are reasonable. There are wide variations of judgment as to what is reasonable. Regarding light that blinds the eyes of another driver, when that work was started some years ago there was one engineer who insisted that any light of more than 100 cp. should be forbidden. The compromise finally reached was eight times that amount of candlepower. Many people expressed their judgment; the Committee adopted a value that seemed to be tolerable and attainable by available commercial products, for the commercial situation must be considered.

The view we have taken at the Bureau in dealing with the subject is that uniformity of requirements among the States is essential, although reasonableness and practicability are equally important. We invariably refer State and city officials to the current specifications that have been worked out jointly by the Society and the Illuminating Engineering Society. This development of joint action among the Eastern States is a most hopeful sign, and is an outstanding example of most effective cooperation between State officials. So far as the approval of types of device is concerned, it seems to me that we have gone as far as there is any use of going at present. We cannot expect now to get requirements that will be more satisfactory than those now established. Nevertheless, the report comes time and again that conditions on the road are worse than they used to be. That is probably because there are more cars and the improvement in the adjustment of the lights has not been great enough to counterbalance the growth in their number. I believe that the average car is in better shape than it was a few years ago so far as lighting is concerned, but there is no doubt that conditions have not improved as much as was expected, and that is largely because this approval of devices is only the first step. In fact, some of the approved devices often are worse than a plain glass would be, so far as throwing light in the eyes of another driver is concerned. I say that deliberately; some of them are worse than nothing if they are not adjusted properly. Moreover, a majority of them are not adjusted properly.

To bring the subject before the police authorities in the District of Columbia we made inspections recently on some 400 cars. They were taken at random as people came in in response to an invitation. Of these 400 cars, our men who made the adjustments considered that between 5 and 6 per cent really had their lights adjusted properly. Around 30 per cent had them in fair shape and more than 60 per cent were positively bad. Of the new cars, those that had been in service 3 months or less, the percentage that were bad was nearly as great as on the old cars. In other words, of the cars that came out from the dealers within the previous 3 months, more than 50 per cent had lights that were positively glaring. That is somewhat of a reflection on the men who build and sell cars; they should see that lights are in proper condition to begin with. Our view is that the next step to be taken is that of education, not merely of the builders and the dealers, but of the driver who must keep lights in adjustment and of the garageman so that he can assist in it. One difficulty is that there is no profit in it; the ordinary garageman is not concerned with spending time on a car unless he gets some profit out of it. He feels that he cannot charge enough for adjusting lights to make it worth his while, therefore he will not bother about it. That is the point of greatest difficulty at present. If the Society and other organizations can make arrangements that will make it appear worthwhile to the average garageman to give more attention to this problem, either through direct pay for the work or through emphasizing that a gain in good-will and in advertising ought to pay for it, progress can be made, but the next step is this campaign of education and the Society is in a strong position to help it along.

MR. CRANE:—What is the best opinion about the use of properly adjusted head-lamps? In other words, if one is driving a car with properly adjusted head-lamps on a road insufficiently illuminated by other means, is it believed to be necessary to shut off those head-lamps or to dim them on meeting another car? In the vicinity of New York City, it has been customary for some years with many people to dim their head-lamps or to cut them off on meeting other cars and, in my opinion, this results in a highly dangerous condition that frequently leaves both cars with insufficient driving illumination. So far as I know, no laws have taken cognizance of this point, except in Massachusetts, and I know of no regulations on the subject.

JAMES J. SHANLEY:—There is no obligation on the part of any driver to dim his lights anywhere in New Jersey and no such legislation is contemplated. My opinion is that a driver should not be compelled to dim his lights. I see no necessity for it if there is a proper device on the car. With dimmed head-lamps, there is altogether inadequate vision of the road.

PROF. R. C. GOWDY:—I have been interested in head-lamps for several years and have done considerable road and laboratory testing. As a result of this experience I believe that adequate spread and uniformity and smoothness of distribution are the most important factors in road illumination. More attention should be paid to the *S* points in the S. A. E. Recommended Practice for Head-Lamp Illumination; that is, to the light on the road 43 ft. ahead of the car and 9 ft. on the side. I am not sure that the present values should be included in the legal requirements, but these points should be kept in mind when engineers are selecting devices with which to equip their cars. Uniformity and smoothness of distribution are essential, particularly on rough roads.

The automotive engineer is interested in making cars pleasing to his customers. The psychological effect of adequate and pleasing lights that are comfortable to drive with has much to do with the pleasure that the user obtains from the car. Mr. Falge mentioned that the two things that go wrong with head-lamps are the aiming and the focusing. I do not know that the aiming feature can be cared for automatically, but I think the focusing problem can be solved. It is, as Mr. Falge has shown, perfectly possible to design lenses that will be self-compensating to a certain extent, and the same is possible with diffusing reflectors. The compensation, of course, is limited to certain tolerances or variations.

It is only through the efforts of the head-lamp manufacturers that this problem can be solved in this way,

but it is a fact that lamp manufacture has been carried to a point where bulbs are made with sufficient precision so that the focusing feature can be eliminated. The sockets can be fastened rigidly into the reflector so that replacement requires simply the putting in of the new bulb, which must be of sufficiently high quality to come within the tolerances for which the reflector is designed. This eliminates the focusing feature by making it a fixed feature so far as mechanical design is concerned and taking care of the variations in the bulb by optical design. The last device will accomplish the result by a somewhat different means, but both of them tend to eliminate the focusing that is, perhaps, the most prevalent source of trouble. The aiming is a matter of education and, if sufficient importance were laid upon it, the public would finally find out how to aim a lamp if not how to focus it, for the latter is a somewhat more difficult operation.

W. A. McKAY:—As a member of the Lighting Division of the Standards Committee, I have been very active for a considerable period in working with the Illuminating Engineering Society on these matters of specification and test. We feel that the specifications developed are good specifications and that the devices which meet them will certainly give very satisfactory road illumination. Perhaps we have not talked enough about this before this meeting; however, I hope that as a result of this meeting you will take this problem to heart. The Lighting Division believes in the specifications; they were worked out after very thorough tests. We would like to have your cooperation and I feel sure that you will give to us greater cooperation.

ECONOMIC MOTOR-FUEL VOLATILITY

BY STEPHEN M. LEE

THE paper is a progress report supplementing a previous report made by R. E. Carlson on the same subject and covers further investigations made by the Bureau of Standards to secure data that can be used as a basis for estimating the effect of a change in the gasoline volatility on the fuel-consumption of cars now in service throughout the United States. Actual tests began in August, 1922, to determine the effect of four fuels of different characteristics on the number of car-miles obtainable per gallon of fuel, as well as on the crankcase-oil dilution. The earlier paper discussed tests run in summer time. The present paper treats those run under winter conditions. Observations also were made on an engine which was set-up and operated in the laboratory of the Bureau under test conditions.

Descriptions are given of the fuels used, the test-cars, the apparatus, the tests and the test methods. The paper also covers a continuation of the crankcase-oil-dilution investigation, with appropriate accompanying data. The results are discussed briefly.—[Printed in the July, 1923, issue of THE JOURNAL.]

WINTER TESTS SHOW LOWER MILEAGE WITH HEAVY FUELS

BY DR. H. C. DICKINSON AND JOHN A. C. WARNER

SINCE the road-service tests of the four special fuels supplied by the Research Department, made under 1922 summer-weather conditions, gave results that were deemed inconclusive, arrangements were made for a repetition of both series of tests under the winter-weather conditions of 1923 to determine whether the relative fuel mileages for different fuels are dependent on the temperature at which car operation is conducted. The paper is a report upon the results obtained.

Four fuels that bore a relation to those used in the 1922 summer tests were specified and means adopted whereby knowledge of their quality was concealed from the drivers, special emphasis being placed on crankcase dilution and on general performance as reflected by the drivers' comments. The method of test was, for the most part, that of the summer of 1922, with cars operated as usual by their regular drivers, the filling with fuel and oil and the keeping of records being wholly in charge of the technical staff of the company concerned.

The details of procedure are presented, together with voluminous tabular data, and comment is made. A consistent and important decrease in mileage for the winter tests is apparent. The conclusions reached are stated in detail, as a summary, under six divisions.—[Printed in the July, 1923, issue of THE JOURNAL.]

SPARK-ADVANCE IN INTERNAL-COMBUSTION ENGINES

BY G. B. UPTON

ALTHOUGH the proper timing of the spark is as essential as the spark itself and the electrical and mechanical devices for producing the spark have been many, little attention has been given to the study of spark advance. An error in timing of ± 20 deg. in a [illegible] engine, or of ± 15 deg. in most other engines, has been shown experimentally to cause a loss of 10 per cent from the best power and economy, provided other conditions remained the same. Hand or mechanical control can average hardly closer than ± 15 deg. to the correct advance because the speed and the load combinations are constantly changing on the road.

Two important phases mark the spark-advance problem. The practical question as to whether the requirements of optimum spark-advance at various combinations of load and speed are such as might be controlled automatically is apparently answered affirmatively; it can be satisfactorily represented by additive functions, one of speed only and one of load or intake-suction only. Hand adjustment would still be needed to take care of the difference between a clean engine and a

dirty one or of a cold engine. When once an engine has been warmed up, however, automatic controls could maintain the proper spark-advance, thereby increasing in practice the power, flexibility and economy of the engine.

The second phase is that of scientific analysis. Inasmuch as combustion takes time, and as the engine is rotating during the combustion process, spark-advance is essential, for it maintains a definite relation between the progress of the explosion and the motion of the piston of the engine. This relation should be such that half the rise of pressure during combustion would occur at the dead-center position of the piston. Analysis, however, both theoretical and experimental, shows that one-half of the pressure rise occurs substantially at three-fourths of the explosion-time, that is, the interval between the point of ignition and the pressure peak. This, then, is the numerical basis for the relations of explosion-time, engine speed and optimum spark-advance.

The existing data, relating to the explosion-time as affected by the mixture-ratio, the size of the combustion-chamber, turbulence, dilution with dead or exhaust gases and the temperatures preceding the explosion, are reviewed. Density is shown not to affect the explosion-time. The factor commonly supposed to be density, which demands an increased spark-advance as the engine is throttled, is in reality dilution with exhaust gas, which increases as the throttle closes, and the cause of the faster explosion in a high-compression engine than in one of low compression is the temperature preceding ignition.

A simple mathematical law, connecting the explosion-rate and turbulence and derived from experiments on bombs, is shown to be applicable to engines, and the manner of its application to the turbulence factor of any engine is indicated. This opens the way to quantitative experiments on turbulence in various designs of engine, hence to the development of designs for producing the greatest amount of turbulence, if such development should seem desirable, as turbulence is the factor that makes really high rotative speeds compatible with a good power output. An equally important factor in making explosions in engines occur more quickly than those in bombs is the heat produced adiabatically during the compression stroke.

The slowing-up of combustion on account of the dilution of the charge with exhaust gas was measured experimentally, and the results are tabulated and compared with the numerical extent of the dilution. Assuming that the dilution ratio is the ratio of the total charge to the quantity of new gas, the slowing-up of combustion because of dilution is demonstrated experimentally to be about proportional to the cube of the mass-dilution ratio.

The scientifically valuable part of the paper is the naming of the factors that affect the explosion-time of an engine, the giving of mathematical expressions for their laws of action and the finding of the numerical values of constants for such factors as turbulence and dilution. The measurement of the optimum spark-advance is made available as a research method for investigating the reaction rates of combustion, and hence of all that related group of topics now of interest to automotive engineers.

By measuring the optimum spark-advance, the combustion rates of gasoline with and without "anti-knock," or tetraethyl-lead, were measured. Although the quantity used was 20 times the normal amount, no change in the reaction rate of combustion was found when the combustion remained normal, that is, without detonation. When detonation occurred without anti-knock, the reaction times with anti-knock followed those to be expected with normal combustion. Detonation apparently changed the combustion habit as if it produced an abnormal top to the combustion.—[Printed in the August, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN CRANE:—Carded as a fuel and engine session, this meeting is simply another in the long series that we have found to be desirable to enable the members of the Society to keep abreast of the work that is being done constantly on the utilization of fuel. One of the principal activities of the Research Committee and of the Research Department has been the cooperative fuel investigation that has been carried on at the Bureau of Standards for the Society, the American Petroleum Institute and the National Automobile Chamber of Commerce. Through the courtesy of some of the large automobile companies in Detroit, the Society has been able in addition to make other research on a large number of cars. Although the tests have been different, the results of both series are extremely interesting. After listening to Mr. Lee's summary of the work done at the Bureau of Standards, we all realize that there is an immense amount of information to digest. Road tests, as they were conducted at first, were very limited in scope. The Steering Committee had to be educated as to the exact nature of the research work and the tendency was to place too narrow limits on the experiments to be made. As the work progressed, however, the scope has been widened until, during the last 6 months, the Bureau has had an opportunity to begin a search for fundamental facts regarding the amount of variation and, more important still, the cause of the variation in the fuel consumption, or the fuel performance, in fuels of different volatility.

I think it is impossible for anyone who listens to Mr. Lee's paper for the first time to begin to appreciate what there is in it. It is worthy of the most careful consideration by everyone who has anything to do with the design of carbureters, manifolds or engines. I hope that everyone who is interested in this matter will read the paper carefully, examine all the facts and then transmit to the Research Department any questions or suggestions that will aid in clarifying this important subject.

Referring to Dr. Dickinson's paper, I call attention to the point of view of the driver as to the quality of the fuel he thought he was using and what he actually was using. It is a very disturbing thing to me that by giving a driver a low initial point, or considerable volatility below the 20-per cent point, he can be "kidded" into using a fuel with a very high end-point without noticing the difference. Whether the driver may or may not have noticed the difference, the engine "noticed" it. Mileage per gallon and dilution both varied with the high end-point, although the driver thought he was getting a good fuel. In fact, the "square" fuel was not picked out by the drivers as being good, although it is a considerably better fuel.

Proper handling of the ignition has an immense effect on the satisfactory operation of an automobile and on the economy of the fuel used. Just how we can take care of the automatic features that are necessary to circumvent the usually dumb driver's method of handling, I do not know. The driver's handling of the car depends of course upon the locality in which he is using the car. If he is in a congested area where a great amount of acceleration is required, he is likely to leave the spark-advance at the point at which he can accelerate satisfactorily without undue knocking. He will leave it there even when the car is running with a very high inlet-suction. When he does so he obtains, of course, a much

[illegible] mixture, or slow combustion, is [illegible] spark-advance. A higher spark-advance [illegible] without getting a knock when the car is [illegible] speed up than it can be afterward.

THOMAS MIDGLEY, JR.:—In reference to the last point that Professor Upton brought up, that the anti-knock material did not slow up normal combustion, the curve he showed is fine for our advertising department; it does not take about any power and gives all the advantages of anti-knock material. Unfortunately, that condition does not seem to be wholly true. I do not understand why Professor Upton did not get a shade of difference, because, when an engine is heavily overdosed with anti-knock material, there is a slight decrease in the power that is caused apparently by the slowing-down of the combustion. It is not great. It has been confirmed two or three times on the track. Top speeds are not so high when large amounts of anti-knock material are used as when that are not used.

I am frank to admit that we have not made any accurate spark-advance determination such as Professor Upton describes. He states that he used 20 times the normal quantity of anti-knock material. He told me he used 5 oz. per gal. That is just a little more than we are willing to the public and is not what we consider a heavy mixture. Another thing entering there is that the effect is logarithmic. The anti-knock material must be multiplied nearly four times to give twice the effect. I believe that five times the amount would not make a difference in the operation that could be detected readily by the spark-advance. I shall try to take some indicator-cards bearing on this point to get the actual pressure-rise of a perfectly normal engine having no tendency to detonate; for, of course, each engine is an individual. I shall average the results to see if we can detect any difference from or can confirm Professor Upton's results.

H. C. BERRY:—We are familiar with the very hasty retrospective survey that an engineer will make of a situation, how he will draw a few conclusions and go ahead and act on them. It is always gratifying when a man with a scientific turn of mind makes a careful survey of the field, evaluates each little item carefully and confirms those conclusions. I feel very much gratified to find that some conclusions I drew a few years ago have been verified.

An apparatus was designed, put on an engine and tested. We found that an increase of about 3 miles per gal. could be obtained under average conditions. I selected a number of men whom I considered to be the best automotive engineers in that section. I watched them drive their cars. I was surprised to find that most of them, even in flat districts, set the spark so that the engine would not detonate when the car was accelerating normally from low speed; that is, where the least spark-advance could be used. Then they drove at 35 m.p.h. on a level road with that spark-setting. If one will set the spark for that, taking an average car and observing the increase of more per gallon, then put the spark where it should be and run the same car over the same road, he will find that he will get an increase of about 3 miles per gal. That will make it worthwhile to use an apparatus of this kind.

We attacked the problem again, trying to develop a device that would be sufficiently positive and foolproof, something we felt that an automotive engineer would not find fault with it and would be willing to put it on cars of his own production. To our surprise, we found that the weak element in the whole thing was the centrifugal advance that we have been using for so long. To show what the trouble was, if one will make a careful study of what the centrifugal advance is doing and draw a curve based on the speed and the degree of spark-advance, he will find that it will come down and then come up on the regular curve when he runs at full load and low speed. If the jump occurred at high speed, one would not notice it much, but at low speed it introduces rather large irregularities in the performance. We had difficulty in finding apparatus that would get rid of the hunting at the lower end of the curve. I am pleased to say that a manufacturer, who became interested in the problem and worked with us, finally succeeded in turning out something that was entirely satisfactory. He made the curve run straight down to the bottom.

We combine that with a sylphon element, which is simply a brass cylinder arranged so that it can expand and contract, put a steel spring inside it and a linkage, and let the suction from the intake-manifold go in through a small hole. This makes a strong engine that has no tendency to strike or hang up and that gives a motion which is directly proportioned to the suction in the intake-manifold. The linkage connects the intake-manifold with the regular distributor head and there is fine compensation for speed and for suction. One of these pieces of apparatus was installed on an engine about 2 years ago. It has been in daily use in a car, has given no more trouble during that time than the front axle and seems to be foolproof.

The sad part, though, is the patent situation. According to the patent laws in this Country, if a man gets an idea that has any utility at all, even if it is only a partial idea, he can get a patent on it. One man noted one phase of the automatic spark-advance problem, a second man another phase and a third man a third phase, and they took out three separate patents. I think it would be impossible to develop any of those ideas separately and work it into a usable automatic spark-advance; together, they would work well, but no one man controls all the patents. As a final word, before anyone uses an automatic spark-advance of this kind, he should make a careful survey of the patent situation. I am not sure that the work I was interested in ever will result in a patent, but the apparatus that was developed there is thoroughly workable. If any one is interested, I shall be glad to explain it in detail. If I do get a patent, it will not stand in the way of any man who is getting out a good ignition system. I am not an ignition man. This is only a sort of sideline that we became interested in.

S. W. SPARROW:—One of the interesting facts pointed out by Professor Upton is the slow rate of the initial burning. This fact must not be overlooked in adopting any automatic device for advancing the spark, or in estimating the rate of combustion in an engine from the spark-advance at which the maximum power is obtained.

The initial burning is to some extent analogous to the burning of the fuse of a firecracker in that the quantity of material burned is extremely small, although the time consumed in burning this small amount is a large proportion of the total. Some engines require a much greater spark-advance than others and yet show no lower efficiency. The probable explanation is that in both engines the bulk of the charge is burned at nearly the same point in the cycle and in nearly the same time, although the initial period of burning of one is much longer than that of the other. If the firecracker just mentioned furnished

power for the engine, it is evident that doubling the fuse length would double the total time of combustion. The engine power, however, would not be affected appreciably by such a change, provided the firecracker proper burned at the same point in the cycle and in essentially the same time as before.

It seems, therefore, that we should use caution in assuming that the spark-advance in degrees before the top center represents three-quarters or any other definite proportion of the total time of burning. The possibility is too great that some minor change in the combustion-chamber design may considerably alter the total time of combustion, without changing appreciably the point in the cycle where the major portion of the burning takes place. I know of a case in which the screwing of a short length of pipe into the spark-plug hole and then putting the spark-plug in the end of this pipe increased the spark-advance required very much but did not change the power or the specific fuel-consumption appreciably.

PROF. R. E. WILSON:—Regarding the effect of dilution with exhaust gases on the rate of explosion, the data for which were derived experimentally as I understand it, might not the observed effect be due merely to the change in the pressure at the time the combustion began? In other words, the pressure, at the time of ignition is, of course, not the same with intake-manifold suction as without it, and therefore one would expect the initial rate of flame propagation to be different and in the same direction as it was found to be; that is, the flame velocities at low throttle-openings corresponding to high dilutions would be lower. How much of the observed effect was due to dilution and how much to pressure?

A second point on which I am not clear relates to the method by which the curves in Fig. 6 of Mr. Upton's were obtained. One curve for flame velocity shows a constant velocity throughout the time of burn; was a constant velocity the assumption on which the curves were derived, or just what is the significance of the figure?

PROF. G. B. UPTON:—Regarding the effect of the change of pressure, the explosion-time is entirely independent of the initial pressure or the density of the gases; it has nothing to do with them at all. Laboratory experiments have covered pressure ranges preceding ignition of the order of 75 to 1; from atmospheric pressure to a pressure of 1100 lb. per sq. in. The time of combustion is independent of the initial pressure, at least within that range, which is very much wider than the range covered by throttling the engine. The thing that we have been calling a pressure effect in the cylinder is dilution. It is not pressure at all.

As to Fig. 6, I made an initial assumption that the flame velocity is variable and that it varies in direct proportion to the time from ignition, starting at zero and increasing in direct proportion to the time. That assumption is not true, but it is a sufficiently close approximation so that a geometrical case can be worked out and our ideas shaped as to what happens.

CHAIRMAN CRANE:—During the last 2 years we have been running tests on an engine of the overhead-valve type having a 4 to 1 compression-ratio and a rather early inlet-valve closing, which gives probably the maximum actual compression for that ratio. We have tried the engine with both single and double ignition. It has a perfectly cylindrical combustion-chamber, with diametrically opposite spark-plugs when double ignition is used, and with a spark-plug on the side for single ignition. With single ignition and at say 1200 r.p.m. at full throttle, a spark-advance of approximately 60 deg. was required. With two spark-plugs, a spark-advance of about 35 deg. will give the same result; in other words, that is the optimum advance in each case. It also represents equal power in each case as nearly as we could measure it with ordinary brake equipment. It is obvious, however, that the pressure in the cylinder when ignition is started is considerably greater in one case than it is in the other. I would be much interested to see what effect the pressure at the time of ignition has on the explosion time.

HERBERT CHASE:—As I understand it, Professor Upton defined the explosion-time as the time from the passage of the spark to the completion of the combustion. He speaks of the completion of the combustion as coming very close to the top of the card. Unless our eyes deceive us, we know, by observing almost any engine running without an exhaust-manifold, that the combustion is seldom entirely complete, even when the exhaust-valve opens which, of course, is comparatively near the end of the stroke. Just what does Professor Upton mean by the completion of the combustion; does he mean that the combustion is actually complete or nearly complete at the top of the card under all conditions?

PROFESSOR UPTON:—The case of spark-advance cited by Chairman Crane is geometrically interesting. If the two spark-plugs were symmetrically placed and cut the flame travel approximately in two, the expected change of combustion time would be as the $\sqrt{2}$ which would change the spark-advance of 60 deg. to about 32 deg.; he said it was 35 deg. Apparently, he gives another check on what I said was the empirical law of the effect of the distance of the flame travel. The explosion-time is cut in proportion to the square root of the distance of the flame travel.

CHAIRMAN CRANE:—The point that I wished to be considered was that, in one case, the start is under entirely different pressure conditions from those in the other case.

PROFESSOR UPTON:—Earlier in the compression stroke.

CHAIRMAN CRANE:—And at a distinctly lower compression.

PROFESSOR UPTON:—Yes. It must be far enough away from dead-center; 60 deg. would be rather far. The start is in the early stages of the flame travel when it has not done much, and the rate of the combustion must be fixed more toward the end where it counts most. Of course, the spark-advance must be affected by the lower initial compression. The reason is that the rise of the temperature during compression has not reached so high a stage at the time of early spark-advance as it would reach with a later spark. The temperature produced by adiabatic compression is an important factor in the spark-advance. The higher the compression-ratio is, the higher the temperature preceding the ignition is and the more rapid the combustion will be.

I think Mr. Chase's eye deceived him. When an engine is running at full load and high speed the exhaust-pipe is at a red heat. The gases are hot enough to be red-hot and to make the exhaust pipe so. They would begin to be red-hot at about 1000 deg. fahr., and the exhaust temperatures would rise to 1600 and 1800 deg. fahr. with full-power operation of the engine, so that the thing ought to look red-hot.

One can see when the end of the combustion occurs by a spectroscopic examination through a window in the combustion-chamber. The end occurs slightly after the pressure-peak. The reason is that, in the chemistry of the combustion, neither hydrogen nor carbon can burn completely at the higher temperatures at the top of the combustion. H_2O and CO_2 must be dissociated partly at the extremely high temperatures and they cannot com-

[illegible] —It may be that my eyes deceived me, but I [illegible] engines running without an exhaust-pipe [illegible] flame from the exhaust port burning as far as [illegible] from the engine. It may be that gas at that temperature [illegible] after it is not burning, but I doubt that such is the case. If it is visible, perhaps my conclusions are wrong, but I still think that oftentimes the gas coming from the exhaust of an engine is still burning when it leaves the port. If by "complete combustion" [illegible] using up of all the oxygen in the cylinder is meant this may well occur in some cases at or near the top center, but after burning often takes place when the exhaust-valve opens. There is no doubt about it and I believe Professor Upton will grant that I am correct in this.

PROFESSOR UPTON:—Possibly; with a rich mixture, it would be unique to burn.

A. J. SCAIFE:—Would the early opening of the exhaust valve have some effect on that?

PROFESSOR UPTON:—I cannot say that it would have much effect. If the gases were held in longer with a later exhaust-valve opening, they would cool a little before they were turned loose but it would not make much difference. I am inclined to think that a visible flame from an open port means a rich mixture and that combustion is still going on. A yellow gas would mean that the carbon part was still unburned.

PROFESSOR WILSON:—Professor Upton's observation that the pressure makes no difference in the time required for the explosion is, of course, very interesting and an important one. I wonder just how it can be reconciled with Mr. Midgley's interesting observations in which he showed that the speed of the flame travel is proportional to some power of the absolute temperature and to the density of the charges? Some equations were worked out which gave a very real value for the exponent n, under conditions such that dilution could not account for the result; in other words, it was taking care of the change of the pressure as the explosion was going on. Professor Upton's experiments would appear to indicate that n was zero.

MR. MIDGLEY:—The value of n that we have, treating it in that particular way, is 0.9. The value found by treating it in another way was 1.1. The space velocity of the flame would be the same, because there would be twice as much gas and twice as much burning, thus requiring the same time. If the value of n is 1.0, everything checks perfectly.

R. W. A. BREWER:—The data that have been presented are so comprehensive that it is not possible to say much, except to ask for a little more information on one or two points. I think we should have an exhaust-gas analysis of the two fuels that were dealt with in Mr. Lee's paper because, from the information which depends on the setting of the fuel needle, it is impossible to say exactly what is happening in the combustion process. It would appear that leaning the fuel needle wider for the less-volatile fuel would lead to a combustion efficiency that was [illegible], but we have no such indication thus far, and I think we should have. We might get it from an exhaust-gas analysis or from a carbureter-characteristic curve. If such a curve were included, it would add very much to the value of the paper.

CHAIRMAN CRANE:—You will find the carbureter-characteristic curve in the complete report.

MR. BREWER:—In that type of carbureter the characteristic is peculiar. Was it a Kingston carbureter?

STEPHEN M. LEE:—A Kingston L-4 carbureter was used.

MR. BREWER:—It has very curious methods of "richening" and "leaning" the mixture according to the speed of the engine, and not in straight-line curves.

CHAIRMAN CRANE:—Those curves have already been made and published.

MR. BREWER:—Do they give information as to how much or what percentage of the combustion has been used efficiently? It is conceivable that although the needle may have been opened more for the least-volatile fuel, that fuel may not have been burned at all. It probably has been burned partly; it seems likely that much of it has been discharged into the exhaust, and this fact might account for the flames that Mr. Chase mentioned. All kinds of compounds may be forming in the exhaust that we have attributed to something which may not exist.

CHAIRMAN CRANE:—The Bureau of Standards is trying to cover all these points. Mr. Lee will tell us what information is to be published.

MR. LEE:—If two fuels such as *B* and *D* are used under conditions such that there is no difference in the fuel consumption per horsepower-hour and no difference in the power output, it is evident that the fuel flow was the same in each case. Any difference in needle-valve opening would then seem to be due to a difference in the fuel viscosity. There is a difference in the viscosity of about 10 per cent between the fuels.

In comparing the two fuels, the characteristics of this particular carbureter did not seem to me to be of sufficient interest to be put into this report. However, they were included in the progress reports that were sent to members of the Steering Committee.

CHAIRMAN CRANE:—I think it is desirable that all such information should be published for the benefit of all the members of the Society. The Steering Committee is not trying to keep anything secret; in fact, the more widely these data can be published and the more they can be thought about and commented on, the better the Steering Committee will like it. We cannot begin to reach all the possibilities. Mr. Lee showed me other curves of those temperatures that I think ought to be and I hope will be published. They are not exhaust-gas analyses but are the exhaust temperatures taken from the individual cylinders. They gave some interesting information on the very faulty distribution that is known to exist in this particular engine.

MR. BREWER:—Could we have a few examples of exhaust-gas analysis in the final report?

CHAIRMAN CRANE:—I hope we shall have them because I think they are desirable.

MR. BREWER:—Especially if they could be taken from separate valves on the same engine.

CHAIRMAN CRANE:—We can try to do that.

W. S. JAMES:—One point that should be taken into consideration is the burning of the oil. An exhaust-gas analysis will include not only the products of the combustion of the fuel, but also the products of the combustion of the oil. The distribution of the oil may be poor and, for the study of distribution, an analysis of the exhaust gases alone may give confusing results.

CHAIRMAN CRANE:—Mr. Brewer's idea is one that I hold; that it is just as well to make a few analyses to see whether they indicate anything. I agree with Mr. Lee that there should not be any noticeable difference in the use of the fuel as indicated by the power-measuring appa-

ratus; the apparatus for measuring the amount of fuel used is apparently the same in both cases. There should not be very much difference in the gases coming from the exhaust pipe, but if the information were available it might show something.

MR. BREWER:—In view of the low temperatures at which these tests have been made and the notoriously faulty distribution, I think it would be unwise to jump to a general conclusion that, because certain adjustments have been made, the results of the combustion are at all comparable. They may not be comparable. The final results may be more or less comparable, but the individual processes may be entirely different without confirming the conclusions that might be drawn from a very much more detailed examination, if that could be had.

CHAIRMAN CRANE:—As I have explained, when we started out this whole investigation was rather restricted in scope. To begin with, the Bureau of Standards had a limited amount of money to spend, and only gradually could the scope be widened so that the investigation can be conducted on really broad lines, as it should be. Originally, we tried to find out whether there was any difference between the fuels in the mileage to be obtained per gallon of gasoline. That was about all we were allowed to attempt. Even if we found that the mileages were different, we were not supposed to know very much as to the reasons, but only that the fuels were different. We are now trying to find out where such differences are most likely to occur, and when those points have been discovered to find out why they occur at those points.

We ourselves may be vulnerable. We know we are vulnerable when we design carbureters that have a very serious viscosity factor. We are working with something that is evidently bad for us on account of the wide variety of fuels we must use and the wide variety of temperatures that we encounter. On the subject of viscosity, we start with a cold engine and we need a rich mixture anyway, but we finish with a hot engine. I suggested to the oil companies that if they could give us gasoline of low viscosity when it was cold and of high viscosity when it was hot, we would appreciate it greatly.

C. H. KINDL:—We should not lose sight of the fact that although we might take into consideration the throttle effect in the designing of a mechanism that combines both the speed and the throttle opening for a particular engine, yet we cannot combine in that design features which will take care of the engine after it has operated for 5000 miles. Variations in compression, fuel ratios and carbon in the cylinder, affect the proper optimum advance so that the delicate adjustments that were made primarily are almost useless and, for that reason, a lever on the quadrant of the steering-gear must be provided so that the operator can adjust the spark-advance to take care of the condition of the engine.

Although we may provide a very intricate mechanism to give the maximum economy, we still must put the whole operation into the hands of the driver to take care of conditions that will change as the engine becomes older. In that light, the expense and complications seem almost useless if the operation cannot be taken out of the hands of the driver entirely.

C. B. DICKSEE:—Some tests made by the Westinghouse Electric & Mfg. Co. to determine the effect of a change in the mixture-strength on the optimum spark-advance are of interest. These tests were made on a Westinghouse single-cylinder E-60 air-cooled engine, having a 3⅜-in. bore and a 5-in. stroke, and a compression-ratio of 4 to 1 at the time of the test. The combustion-chamber was cylindrical, the spark-plug passing through the side of the cylinder at right angles to the diameter on which the valves lie. During some experiments to determine the effects of the mixture on the cylinder temperature, it was noticed that a considerable variation in the spark-advance was necessary after a change in the mixture; therefore, a few tests were made to ascertain the relations between them.

During one series of tests, pressure-time cards were taken on a Midgley indicator so that the effect of the change on the combustion line could be observed and also with a view toward obtaining some idea of the time required to produce the maximum pressure after ignition. For this latter determination, some means of locating a point on the pressure-time diagram definitely is needed urgently. For want of anything more definite, several diagrams were taken with the ignition momentarily switched off, the top dead-center position being obtained by drawing a line parallel to the atmospheric line about half-way up the diagram. A point half-way between the points of intersection of this line with the compression and the expansion lines was taken at the top dead-center. One of these curves was transferred carefully to a piece of thin celluloid that was graduated in 5-deg. divisions on each side of the top dead-center. To use this instrument, the atmospheric lines of the instrument and of the diagram were made to coincide, and the celluloid was slid along until the compression lines coincided also. It was easy then to determine with fair accuracy the top dead-center and mark off the ignition-point, which was obtained by a rotary spark-gap. This method is open to obvious objections but, as the indicator is now built, no more direct or accurate method seems to be available. The spark position was obtained by advancing by steps till a further slight advance produced no change in the speed. This method is not to be compared with that of taking readings at different settings and obtaining the optimum from a curve of results, but the results described here are a preliminary to work that it is hoped to carry out in more detail in the near future.

In all, three sets of readings were taken. In two of the sets the spark position was adjusted as described and, during one of them, pressure-time diagrams were taken. In the third set the spark was kept constant at the advance called for by the chemically correct mixture and pressure-time diagrams were taken. The mixture was

TABLE 3—RESULTS OF TESTS WITH VARIABLE SPARK-ADVANCE

Run No.	407	408	409	410	411	412	413	414	415	416	417	418	419
Speed, r.p.m.	1,260	1,250	1,260	1,250	1,260	1,240	1,240	1,250	1,260	1,250	1,265	1,250	1,255
Power Developed, b.hp.	5.90	5.97	6.00	5.82	5.71	5.24	5.04	4.66	6.06	5.85	5.61	5.24	5.45
Fuel Consumption, lb. per b.hp-hr.	0.956	0.826	0.755	0.677	0.652	0.631	0.575	0.606	0.700	0.644	0.638	0.625	0.587
Mixture-Strength	12.0	12.5	13.1	14.4	15.1	16.3	18.1	19.3	13.4	14.5	15.6	16.8	16.8
Spark-Advance, deg.	27	27	26	21	25	31	45	61	30	27	24	24	5
Time to Reach Maximum Pressure, sec.	..	..	..	..	..	..	..	..	0.0049	0.0044	0.0041	0.0095	0.0063

TABLE 3—RESULTS OF TESTS WITH A CONSTANT SPARK-ADVANCE

Mixture-Strength	Spark-Advance, Deg.	Time to Reach Maximum Pressure, Sec.
[illegible]	[illegible]	[illegible]

discussing from exhaust-gas analysis conveyed by Ledoux tubes. All readings are at full throttle, the speed being maintained as near 1250 r.p.m. as possible. The means that the crank passes through an angle of 7 deg. 30 min. in each 0.001 sec., and facilitates the taking of time measurements from the diagrams. The results of the experiments are given in Tables 3 and 4. Table 3 gives results of the test in which the ignition-point was adjusted to suit each condition. In Table 4, the spark-advance was maintained constant.

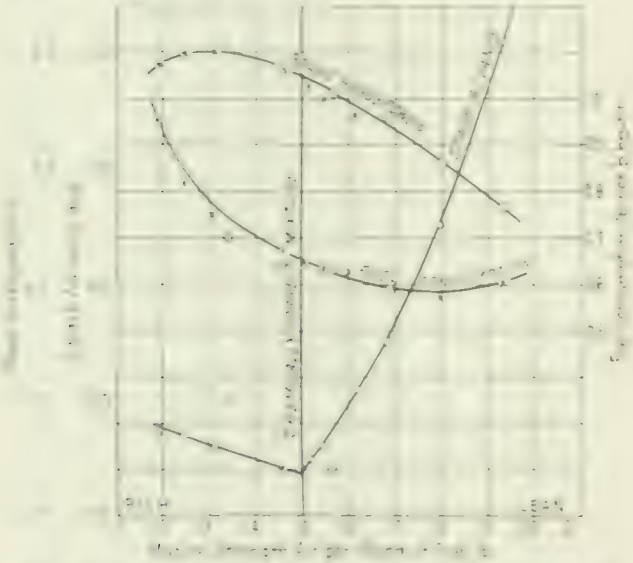


FIG. [illegible]—CURVES SHOWING THE SPARK-ADVANCE THAT IS REQUIRED WITH VARYING MIXTURES AND THE RESULTING FUEL CONSUMPTION AND BRAKE HORSEPOWER

The results of the tests are shown also in the accompanying curves. Fig. 10 indicates the spark-advance necessary for various mixtures and the resulting fuel consumption and brake horsepower. Fig. 11 shows the time to reach the maximum pressure plotted against the mixture strength, both when the spark-advance is varied and when it is kept constant.

It will be seen from Fig. 10 that the spark-advance required for a given mixture-strength does not agree exactly with that given in Fig. 1 of Professor Upton's paper. His experiments gave a minimum advance when the mixture was chemically correct; that is, 15 lb. of air per pound of gasoline. This is rather what one would expect as, under these conditions, the dilution is a minimum and consists solely of residual exhaust products. There are natural differences between the two engines upon which the tests were run, one being air cooled and having a cylindrical combustion-chamber, the other being a water-cooled machine with the valves at the side that produces a combustion-chamber that is shaped very differently. The compressions of the two engines probably are different also. The hotter cylinder of the air-cooled engine together with the more compact form of combustion-chamber undoubtedly will tend to increase the rate of flame propagation and thus reduce the advance necessary; and also it may influence the mixture at which the maximum propagation is produced.

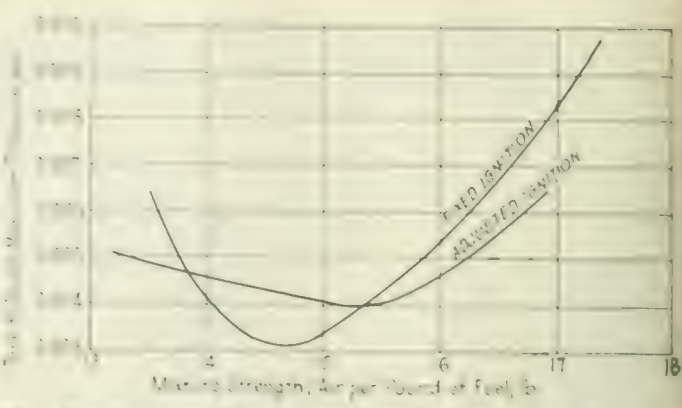


FIG. [illegible]—CURVES IN WHICH THE TIME TO REACH THE MAXIMUM PRESSURE HAS BEEN PLOTTED AGAINST THE MIXTURE-STRENGTH FOR A VARIABLE AND A CONSTANT SPARK-ADVANCE

The shapes of the two curves also differ somewhat in that the rate of change of ignition with the mixture-strength is less for rich mixtures and greater for lean mixtures, according to our test; and, with the 15 to 1 mixture, a sudden change in direction appears that produces two distinct curves instead of the one continuous curve derived from Professor Upton's experiments. These differences probably are attributable to the difference between the two engines, and a comparison of the results given by widely different engines should help to elucidate the influence of the differences of design on the advance necessary and on combustion problems.

The two curves shown in Fig. 11 do not agree fully, as the time to reach the maximum pressure should be the same for both curves with a mixture in the neighborhood of 15 to 1. With the limited number of diagrams available, however, an absolute agreement could not be expected but, by averaging a larger number of diagrams, a much closer agreement should be obtainable. The curves do, however, give a general idea of what can be expected.

A point well worth noticing is shown in runs Nos. 418 and 419. In run No. 418, with an angle of advance of 24 deg., the time required to produce the maximum pressure was 0.0095 sec. Under exactly similar conditions

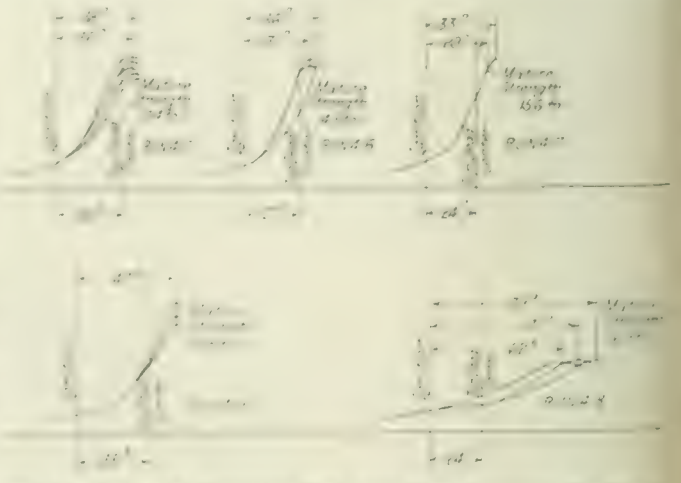


FIG. [illegible]—DIAGRAMS SHOWING HOW THE TIME REQUIRED TO REACH THE MAXIMUM PRESSURE WITH A GIVEN MIXTURE VARIES WITH THE SPARK-ADVANCE

but with the spark advanced 35 deg., the time to produce the maximum pressure fell to 0.0063 sec. This indicates that the time required to produce the maximum pressure with a given mixture varies with the spark-advance. This is clearly shown in Fig. 12, which gives the combustion line from the pressure-time diagrams of runs Nos. 415 to 419, the difference between the combustion line for Nos. 418 and 419 being very marked. A further investigation of this point would form an interesting study and might throw light on the phenomena of combustion in a closed cylinder.

As already indicated, these tests were of a preliminary nature and it is hoped to go further into the matter at an early date. The figures for time obviously cannot be considered as other than approximate, on account of the method necessary for locating a point on the pressure-time diagrams. A similar investigation carried out on a slow-speed engine, using an ordinary indicator but with the drum rotated by a positive drive from the crank-shaft, would supply some very valuable information.

PROFESSOR UPTON:—Mr. Dicksee raises three points; (*a*) that the curve of the optimum spark-advance versus the mixture-ratio, other conditions remaining unchanged, is perhaps two-branched, the branches joining at the theoretical 15 to 1 ratio; (*b*) that the time of the half-pressure rise is highly variable from the value of 0.75 of total combustion time, given as good in my paper and (*c*) that the time of combustion is itself variable with the spark-advance and is shorter with the greater advances.

The weight of evidence is against the idea (*a*) that this curve is two-branched. Figs. 1 and 2 of my paper show that, in the bomb experiments, the curves of the combustion-time versus the mixture-ratio are single curves. We have taken many curves in our own engine work, such as those of Fig. 3, and all are of the type of Fig. 3. We estimate the accuracy of the hand setting for the optimum advance by watching the dynamometer, at about ± 5 deg. If Mr. Dicksee will apply this probable error to the points with which his curve is plotted, he probably will concede that his curve need not be two-branched.

As to (*b*), I have summarized in Tables 1 and 2 of my paper the type of our results with indicators, taking pressure-time curves on a low-speed engine. The range of variation of the factor is 0.65 to 0.85 for individual observations and 0.71 to 0.81 for averaged groups. The factor seems to depend on the mixture-ratio, being greater for lean mixtures. We have no indicator-cards of our own from speeds above 1000 r.p.m.; but the cards published by Judge[3] fall in this same range of values. The value 0.75 was suggested only as a fair average.

In regard to (*c*), Table 1 of my paper shows perhaps the same tendency as is noted by Mr. Dicksee, though in a much less degree. It shows in our data only on lean mixtures. One might expect the combustion to be somewhat quicker with an earlier spark, because the turbulence is then greater, especially in a valve-in-head engine. But this turbulence effect might be overcome by the fact that the compression-ratio, during the early stages of combustion, is lower with an early spark than with a later one. This phase of the problem is complex and probably very much a matter of the individual engine.

[3] See High-Speed Internal-Combustion Engines, by Arthur W. Judge.

WIRE WHEELS

(*Concluded from p.* 204)

precision fit. The method of machining the driving flange is somewhat novel, although it has been known to many who are familiar with lathe backing-off attachments that are used for making form milling-cutters, hobs and the like. The mechanism for machining the hub corrugations is a specially developed engine-lathe, driven by gears of the correct ratio to produce the required number of in-and-out motions of the tool-slide, which is connected to an eccentric shaft of a certain throw corresponding to the depth of the corrugation required. The taper is obtained by setting the tool-slide at an angle with the corresponding hub-shell driven member, which in turn is made equally accurate on a coining press.

The positive locking hub-cap shown in Fig. 5 consists of two principal members, the inner member, known as a corrugated sliding barrel fitting into similar corrugations in the outer member or hub-cap proper. This sliding barrel is held under tension by four springs, having approximately 15-lb. pressure per spring, and the barrel in operation having a movement of approximately $\frac{3}{8}$ in. The barrel is operated by a special wrench with a puller and cam lever so that the full travel of the barrel is obtained by moving the lever through 180 deg.

In assembling the cap to the hub, it is necessary first to withdraw the sliding barrel by using the wrench and its attachments; the hub-cap then is screwed into place and the sliding barrel is released. The wrench should then be tightened more and, upon reaching its proper position, the teeth on the inner end of the sliding barrel snap into mesh with the corresponding teeth on the hub itself, giving an absolutely positive engagement until the sliding barrel is again withdrawn.

Although we believe that the wire-spoke wheel is the best that can be made for automobiles at the present time, developments have often been brought about that have caused a reversal of what has seemed to be well founded experience; and it may be that, in the future, a wheel will be developed that will embody the good points of the wire wheel and perhaps have certain advantages over it. What kind of wheel this will be we do not know, but so far as our present knowledge goes, we believe that a steel wheel is, without question, better than a wood wheel, and that a wire wheel, properly built, is the logical wheel for an automobile, whether considered from the viewpoint of safety, strength, economy or appearance. [The discussion of this paper is printed on page 211.]

Rear Axles for Trucks

By E. Favary[1]

Membership Section Paper *Illustrated with* Drawings

On account of the pressure upon the space in recent issues of THE JOURNAL which made it necessary to withhold publication of the paper itself for several months, it was also necessary for a departure to be made from the usual practice of publishing a paper and the discussion following its presentation in the same issue of THE JOURNAL. This paper was published last month and the discussion following its presentation is given below. As is the custom, an abstract of the paper precedes the discussion so that those of the members who did not read the paper when it was printed in the August issue of THE JOURNAL can gather some knowledge of the subjects covered by reading the abstract if they do not wish to take the time to read the complete text.

ABSTRACT

THE five types of final drive now in use on motor vehicles are stated by the author to be (*a*) the internal-gear, (*b*) the bevel-gear, (*c*) the worm-gear, (*d*) the double-reduction and (*e*) the internal-gear. The advantages of each type as emphasized by its maker are presented and commented upon, and the same procedure is followed with reference to their disadvantages.

Following these comparisons of the different drives, which cover about the first third of the paper, the bearing loads and shaft stresses of typical semi-floating and full-floating axles are calculated for the conditions (*a*) maximum torque plus the normal radial load on the wheel, (*b*) the wheel locked and skidding forward when the brakes are applied and (*c*) the wheel skidding sidewise while the truck is moving. A tabulation of the results obtained from the mathematical calculations is included. The author concludes from these results that while the maximum shaft-stresses are practically the same in both designs, the shaft in the full-floating axle can be made lighter and that a higher factor of safety should be employed in the semi-floating axle since the bending stresses are continually reversing. As the bearing loads in the full-floating axle are considerably heavier, a greater bending moment is imposed on the axle housing, thus increasing the production cost of this axle because of the necessity for heavier bearings and axle housing.

The last third of the paper is profusely illustrated with photographs and drawings of various types of rear axle. These include the rear axle of the Class B truck, as well as commercial examples of the worm drive, internal-gear drive, axles with load-carrying members of different materials, double-reduction axles and an example of a chain drive. [Printed in the August, 1923, issue of THE JOURNAL.]

THE DISCUSSION

Chairman T. Myers:—At the request of Chairman H. W. Slocum, I have reviewed the excellent display of truck rear-axle design given in Mr. Favary's paper, with respect to the possibilities for standardization. To attempt specific recommendations in detail calls for a complete and arduous study of the design of each type of axle and a careful comparison of points. Naturally, I have not had the time to make such a study.

A casual glance through Mr. Favary's paper by a member of the Society's Standards Committee will cause him to contemplate with awe the enormous investment in axle spare parts it must entail to service the different makes of motor truck already in operation. Further contemplation multiplies this by the amount of different manufacturing tool equipment necessary to produce them, and the terrific expense it must entail to keep the many little armies of salesmen each fighting their 20-sided battles over unimportant detail. I have enumerated 12 features of the various axle designs that seem to offer more or less attractive fields in which to pursue the well-defined and enormously profitable policy of standardization, that has been steadfastly fostered by the Society of Automotive Engineers. These are included in my paper Notes on Motor Trucks.

The various types perform exactly similar functions in a variety of ways; (*a*) they support the springs on which rests the weight of the body and the pay load; (*b*) carry the brakes; (*c*) are supported by the wheel bearings; and (*d*) carry the parts that transmit the engine torque. For equal loads, stresses and similar points of attachment, it is natural to think that the same bearings and proportion and size of parts will serve as well on one axle as on another. In this light we can investigate the present subject by comparing the similar aspects of the various axles.

The range of truck sizes to-day can be divided roughly into seven categories as indicated by their pay-load capacities; namely, $\frac{3}{4}$, 1, $1\frac{1}{2}$, $2\frac{1}{2}$, $3\frac{1}{2}$, 5 and $7\frac{1}{2}$-ton sizes.

All types of rear axle are now so perfected and perform so well that a standardization of all assembly dimensions is the next important move in the progress of the industry.

O. M. Burkhardt:—The duties of a rear axle are numerous. It must carry a large part of the chassis load and, in addition, a still larger part of the weight of the body and the useful load, transmit the engine power to the wheels and transmit the tractive effort or propulsive force. The containing casing must resist the torque due to the drive and, in the case where torque-rods are used, it must also resist the braking load. From this statement it is fairly evident that a clear picture of the proportions and stresses involved must be obtained before the final word can be said as to what type of axle is to be chosen for a particular type of vehicle. In this respect we are very much interested in Mr. Favary's intention of analyzing the stresses involved in different designs, such as semi-floating and full-floating axles, and wish that this analysis included the internal-gear, double-reduction and chain drives.

Concentrating first on a comparison between the semi-floating and the full-floating types of axle, we have within the Pierce-Arrow Motor Car Co. a number of specimens for direct comparison. For instance, we are using the

semi-floating type in all of our passenger cars and on the 2-ton trucks, and the full floating type of axle on our 3½ and 5-ton trucks. The reason for this is entirely a matter of calculation. For instance, to withstand properly the stresses of combined torque and bending, in the case of the 2-ton truck, our live-axle shafts work out to be of such size that no designer would care to go beyond it. The shaft approaches such dimensions that the effect of heat-treatment begins to be questionable, because it is evident that heat-treatment is most effective on thin sections. Hence, if we come to shafts of more than 2¾-in. diameter, the most desirable properties are not obtainable from the steel. In other words, the shaft diameter of our 2-ton truck seems to form a distinct line of demarkation as to how far one can go with the semi-floating axle. It is the simplest and cheapest design for vehicles of less than 12,000 lb. gross weight, but it is impractical for anything above this gross weight.

The full-floating type of axle is somewhat more expensive, but as it is possible to separate the bending stresses from the torque stresses with this type of design, we have a logical stepping-stone to another category of vehicle; namely, those above 12,000-lb. gross weight. The larger bending-stresses, due to the load of the vehicle, are taken by a large-diameter load-carrying tube, and the torque stresses are taken by a solid axle surrounded by the load-carrying tube. The calculations show that, for vehicles of more than 12,000-lb. gross weight, the load-carrying tube and the torque-transmitting axle are lighter than a single member taking both torque and bending. Further, we have a line of demarkation on the 2-ton model or 12,000-lb. vehicle with regard to radius and torque-rods. For instance, in our larger trucks we use radius and torque-rods because the stresses imposed on the springs due to torque reaction would be so great that the springs would need to be much stiffer without these members, to reduce the fiber stresses properly. In case of the 2-ton truck, we found that we were able, with the springs, to take care of the torque reaction without coming into excessive spring sizes. However, it cannot be denied that if a spring is designed stiff enough to take care of the torque reaction, the riding qualities of the vehicle are impaired. The springs are then stiffer than is necessary to carry the static load. In the case of the truck the riding qualities are not so important and, as price is of some consideration, this condition in which the springs take care of the torque reaction is tolerable; but in the case of the passenger car, in which the riding qualities are of supreme importance, a torque-rod must be introduced to relieve the springs of any other duty except that of supporting the load.

With regard to the other types of axle, the internal-gear axle is losing in favor because of the great difficulty of keeping the gears well lubricated, preventing oil leaking out to the brakes and securing a reasonable life for the gears. The internal-gear-drive axle is by far the simplest, lightest and cheapest; but, because of the disadvantages that have been mentioned, the axle is losing in favor.

The double-reduction axle occupies the extreme position, that diametrically opposite to the internal-gear axle. It is by far the heaviest, the most complicated, the costliest and the most difficult axle to repair and maintain in good condition. Therefore, the double-reduction axle has very few admirers or adherents at present.

The worm-drive axle occupies a position in between the two extremes. It is somewhat heavier than the internal-gear type but is lighter than the double-reduction axle. It is simplicity in itself; outside of the differential, only two gears are required. These gears, if properly designed, last almost as long as the truck. The lubrication is taken care of easily. It has proved continuously to be a highly efficient means of power transmission. It is silent in operation, lends itself to a symmetrical design of case and it makes for an axle that one can produce in quantity, which is a point of great importance.

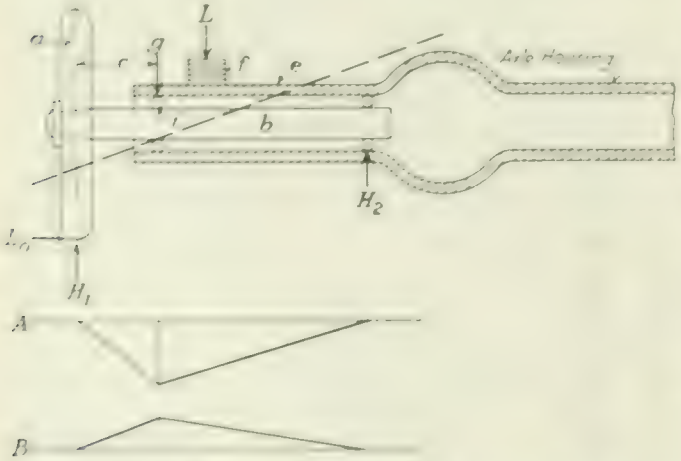
There are satisfactory and unsatisfactory worm-gear axles. In my opinion the best practice is to mount worm gears on ball bearings throughout. It is preferable to anchor the worm shaft on one side of the shaft only, so that the shaft is free to expand without cramping itself. This expansion is a phenomenon that must be well taken care of in case the worm shaft is to be mounted in taper roller-bearings. For instance, if the worm unit increases 200 deg. fahr. in temperature and the length between the bearings is 15 in., we have a total expansion of about 0.020 in. The bearings must be protected against tightness; hence they should be fitted with not less than this amount of clearance at room temperature. By far the best practice is to mount the worm above the wheel. This is to obtain a practically straight-line drive from the gearbox. Lubrication is taken care of easily by providing little troughs in the worm housing. While dwelling on the subject of bearings, it can be emphasized that taper roller-bearings are extremely practical where end-thrusts are not excessive and where a slight end-play is tolerable, such as in the road wheels.

With regard to the design of the worm gear itself, we note from a paper by Kalman Heindlhofer, Tests on Rear-Axle Worm-Drives for Trucks,[1] that worm gears of the ordinary design are subject to failure unless they are made of the proper steel. Mr. Heindlhofer gives several illustrations of broken worm-shafts, and he correctly emphasizes that the failures were due to having made the worms of a straight carbon-steel, instead of from an alloy-steel. There has been an innovation in worm-gear design, emanating from England. The design that I have in mind is known as the FJ type of gear, the letters being the initials of the inventor, F. J. Bostock.

These FJ gears have proved to be extremely successful. The contact area between the teeth is truly symmetrical, instead of being one-sided. The area in contact in extreme cases is five times as great as in the ordinary worms of the involute type. The rubbing velocity is only about 30 per cent of what it is in ordinary worm-gears. This is because the relative motion is mostly a rolling one, instead of being wholly a sliding motion. In fact, the FJ type of gear is closely allied to the spiral-bevel gears. This decrease in sliding velocity and almost pure rolling velocity permits a considerable increase in load. It has been found that the torque capacity of these gears is 25 to 40 per cent greater than that of gears of the ordinary involute design. A peculiar inefficient characteristic of involute design is that the extremities of the lines of contact travel toward each other until they meet and vanish somewhere near the center of the gear. This explains the well-known fact that, when a wormgear of the involute type is overloaded, pitting first takes place on the outside of the wheel and on this side only, while those portions of teeth on the entering side of the wheel remain unmarked.

We have found the spur-gear type of differential su-

[1] See *Mechanical Engineering*, November, 1920, p. 613.



S. A. E. Steel specification No. 2340 in such large diameters as 4 in. usually cannot be expected to allow any more than a 120,000 lb. per sq. in. elastic-limit, considering a commercial run of steel with a low carbon-content. This gives us a factor of safety for the semi-floating axle of 120,000 ÷ 27,100 = 4.4.

In case of the full-floating live-axle, we have a maximum torque-moment of 97,200 lb-in. This gives a stress of 97,200 ÷ 2.84 = 34,250 lb. per sq. in.

A shaft of 2 7 16-in. diameter can be heat-treated safely up to a 145,000 lb. per sq. in. elastic-limit and still be within the realm of manufacturing possibilities. This gives us a factor of safety of 145,000 ÷ 34,250 = 4.25. From this we note that, to all intents and purposes, the two shafts are designed with about the same factor of safety. However, the stresses in the semi-floating axle are reversed with every revolution of the road wheel, from a positive maximum to a negative maximum. This, according to Wöhler's test, is about the worst loading that can be put upon any part. For this reason the factor of safety of a semi-floating shaft should be at least 2½ times as large as that of a full-floating-axle shaft, because the latter is stressed to a maximum uniformly throughout the whole range of driving, with the only exception of occasional use of the reverse gear.

To sum up the situation, I would say that Mr. Favary considers the full-floating live-axle for the 5-ton truck as being 2½ times safer than the semi-floating shaft.

E. FAVARY:—In his statement that the full-floating axle has a factor of safety of 4.25, Mr. Burkhardt considers the rear wheel as slipping on the ground. I discussed this in my paper and said that the wheels will slip when a shaft brake is employed. In the case that Mr. Burkhardt has considered we will obtain a maximum torque-moment of 97,000 lb-in., which is as mentioned in my paper. Taking the smallest dimension of the shaft, that is, 2 7/16 in. in diameter, we find that the polar section modulus of this is 2.84, and that this gives a stress of 34,250 lb. per sq. in. He says that this is the stress in the small end of the shaft and I agree with him. But when Mr. Burkhardt states that steel, heat-treated, has an elastic-limit of 145,000 lb. per sq. in., I entirely disagree with him, because he is considering the elastic-limit in tension and in compression. He admits that we only consider the torque in the full-floating axle; hence, why should we consider the tensile and compressive strength of the steel? We must consider the torsional stresses, which are purely shearing stresses; therefore, on the face of it, knowing that the elastic-limit in shear to be only about 35 per cent of the elastic-limit in tension or compression, it is as I have shown, about 54,000 lb. per sq. in. Let us assume that this elastic-limit of the material in shear or torsion is 55,000 lb. per sq. in. If we divide this by 34,250 lb., we get a factor of safety of less than 2; therefore, in the case of the full-floating axle, where the stresses are purely torsional, I cannot see why Mr. Burkhardt considers the elastic-limit of the material in tension or compression and I hold this to be an error.

With regard to the semi-floating axle, Mr. Burkhardt says that the static radial-load must be added to the dynamic load when the car is skidding. In Fig. 35 the wheel of the car is marked *a*, the axle *b*. The distance *c* is 6 in. The axle housing is indicated by *e* and the spring by *f*. The load *L* on the spring will be pressing downward at *g* and will be resting on the bearing *i*. Under normal load, the top of this bearing will carry the load. Considering the reaction at H_1 and H_2 due to the static load *L*, a positive bending-moment will be created in the

shaft. If the distance c is 6 in. and the load 9000 lb., we have a maximum positive bending-moment of 54,000 lb-in. as shown at A.

Mr. Burkhardt says further that when the car is skidding the dynamic bending-moment is 9000 times the coefficient of friction of 0.6; that is, one-half of the normal load on the rear of the truck, and this is also 54,000 lb-in. I do not agree with Mr. Burkhardt's contention. When the car is skidding sidewise, we must consider the centrifugal force that will tend to shove the car to one side. When that happens the inner wheel is relieved of a certain amount of load and the outer wheel will carry more load as shown in Fig. 1 of my paper. Hence, to begin with, this load is not 9000 times 0.6, but we must calculate the force that causes the car to skid and, as I showed before, this amounts, on the outer wheel, to 10,600 lb. and is the force tending to skid the wheel.

To find the bending-moment due to skidding, consider this force and imagine the left wheel to be skidding to the left. In Fig. 35, L_o is the reaction working in the opposite direction and this creates a negative bending-moment in the shaft, as shown at B in Fig. 35, which must be deducted from the positive bending-moment. Therefore, I disagree with Mr. Burkhardt that those two stresses should be added; in fact, the bearing load due to one load alone may be considerably higher than that due to the two, because the static radial-load is supported by the top of the bearing at g, whereas, when there is a tendency to skid, the shaft will tend to deflect as shown by the dotted line and impose a load at the bottom of this bearing i; hence, we must deduct this load from the former.

A MEMBER:—Can you add it on the inner wheel?

MR. FAVARY:—Yes, but a load of only 300 lb. was left on the inner wheel. The maximum stresses are on the shaft of the outside wheel, because the loads on both wheels do not remain the same when the car skids, and Mr. Burkhardt has not taken that into consideration.

HERBERT CHASE:—Will not the static load on the outer wheel increase?

MR. FAVARY:—Yes, the static load will increase from 9000 to 17,000 lb. as I have shown, and the skidding force will be the radial load multiplied by the coefficient of friction; this amounts to 10,600 lb., as stated in my paper. The bending in the shaft due to skidding will act in the opposite direction and hence we obtain a negative bending-moment due to the skidding and a positive bending-moment due to the static load; therefore, one will counteract the other, and the result is less than that due to the maximum radial-load alone.

Mr. Burkhardt states in the beginning of his discussion that I find the semi-floating axle most highly stressed at the inner bearings, the inner bearings being those near the differential. The stress in a shaft depends on its dimension and I simply stated that if the shaft were tapered, as shown in Fig. 11 of my paper, the shaft being so much smaller near the inner end than at the outer end, I found the metal much more highly stressed near the inner bearing, since the polar moment of inertia here is 2.6 and near the outer end it is almost 12, or nearly four times that near the inner end. By increasing the diameter at the inner end of the shaft, we can easily reduce the stresses. The bending-moment is very much greater near the outer end, but if the diameter of the shaft is here so much larger, as shown in Fig. 11, the stresses are less than at the inner end. The resultant load on the bearings is less than that due to the maximum radial-load, on account of the skidding force, which I have taken into account, but which Mr. Burkhardt is not considering; he adds them together and that is not a true condition of the facts under the conditions assumed when the car skids.

W. F. ROCKWELL:—Mr. Burkhardt's point that the heat-treating in a large shaft may cause considerable trouble, is referred to in a discussion before the British Institution of Automobile Engineers in which very careful tests made on a large billet in connection with gun-forging work and the heat-treatment of gun forgings were reported. Apparently, there was practically no difference in the strength of the test-pieces cut out of various parts of a very large billet that had been subjected to heat-treatment somewhat similar to that employed in axle heat-treatment.

Mr. Burkhardt has said that, in the 5-ton sizes, the full-floating axles can be made lighter in weight than the semi-floating axles. The statistics on American stock axles for 1922 have been published[5] and, inasmuch as the figures were given by the truck-axle manufacturers themselves, there hardly could be any claim of prejudice. If those figures are examined, it will be found that there are at least one or two designs of semi-floating axles of 5-ton capacity that weigh considerably less than full-floating axles of the same rated capacity.

Current statistics show that, in the passenger car field, there has been a very decided increase in the production of semi-floating rear-axles. Semi-floating types increased 15 per cent during the past 3 years, while full-floating construction has suffered a loss of 20 per cent. The majority of live-axle truck-designs in this country has always followed the semi-floating type. In actual tests, it has been proved that skidding into a curb will demolish the wheel without injuring the semi-floating shafts; whereas, in full-floating jobs, such accidents usually bend a tube in addition to breaking the wheel, and the cost of repairs is increased greatly. It happens occasionally that a full-floating tube is bent by a skidding accident, and that the owner is not aware of the trouble until several shafts break in succession; investigation then shows the cause to be a bent tube.

Mr. Favary's calculation of bearing loads proves beyond a doubt that better distribution is possible with a semi-floating design. The great leverage existing, because of the increased distance between semi-floating-shaft bearings, reduces the bearing load due to skidding so that it is less than 30 per cent of the load imposed with a full-floating hub-and-shaft design. For equal capacity, semi-floating axles weigh less than full-floating axles. If the track is the same in full-floating and semi-floating axles, the distance from hub-cap to hub-cap for full-floating axles is usually considerably greater, and there is a decided increase in accidents when the hub-cap or driving flange extends far beyond the tire rim. Other advantages of the semi-floating design are a great reduction in the number of parts and a better distribution of the stresses incident to torque and braking.

With reference to bearing loads, the design shown in Fig. 12 of Mr. Favary's paper differs from the great majority of worm-drive axles in the method by which the worm-gear thrust is taken care of in the differential mounting. In forward drive, the worm-gear thrust is taken by the left-hand bearing; whereas the usual design places this thrust on the right-hand bearing. In this design the bearing loads are very nearly equal on each differential bearing; whereas in the other design the right-hand bearing takes a resultant load approximately 100 per cent greater than the left-hand bearing.

[5] See *Automotive Industries*, Feb. 16, 1922, p. 388.

symmetrical without being

bearings, the factor

is that of the actual design.

adjustment of the worm-

by the use of threaded nuts on the differ-

while some other designs employ shims.

four-pinion bevel-gear-type differentials

with the best American practice for

combined with compact light construc-

tion. The use of the two-pinion differential cannot be

justified except on the grounds of reduced first-cost,

which is offset by increased maintenance.

It will be observed that the wormgear is clamped be-

tween the differential side case flanges and the drive is

taken by bolts that are in shear at two points. This has

an obvious advantage over the single-flange differential-

case that is sometimes used.

Two concentric brakes, both internal-expanding, cam-

operated, are employed in this design. The external-

band wheel brake practically has been eliminated

on trucks in this Country, because the brakes are

liable to be burnt off whenever skid chains are

used and a cross-chain breaks. The mud and grit

that finds its way between the external brake and the

drum has a tendency to cut into the drum very rapidly.

The internal cam-operated brake is the only internal

brake that will not freeze up and become inoperative

when covered with slush and ice in cold weather. The

use of two drums on each wheel permits braking first

on one drum and then on the other in hilly country, so

that there is no overheating. The flanges on the service

brakes prevent them from being distorted, although the

tendency to distort is very slight with an expanding

brake of this type. Hinged and quadrant brakes have

a much greater tendency to distort the drums perma-

nently. Concentric arrangement gives the largest pos-

sible braking surface without sacrificing the strength of

the brake-carrying member. Considering the wheels as

columns supporting a beam, the closer the load is placed

to the column, the greater the factor of safety is for the

same beam. With narrow drums, the springs that carry

the load to the beam can be placed very close to the

wheels, which act as supports.

One of the principal points of discussion concerning

brakes is whether the propeller-shaft or transmission

brake has any advantage over the rear-wheel brake.

From actual experience with both types of brake, we have

drawn the following conclusions: A brake on the trans-

mission or the propeller-shaft requires much larger

transmission members in the axle because the braking

torque imposed on the rear axle cannot be estimated as

closely as engine torque and, in any case, is considerably

greater than it is possible to impose by wheel brakes.

Although the braking effort with the transmission brake

is one advantage is offset entirely by the fact that

it is very easy to make the braking effort too extreme,

with disastrous results to the axle transmission mem-

bers. If the rear wheels are locked, any further braking

effort is useless, we have demonstrated that, with good

four-wheel brakes, the rear wheels can be locked, bring-

ing the truck to a stop in a minimum distance. The use

of a transmission brake would not permit the truck to

stop any sooner and, if its application caused the de-

struction of a shaft, the braking effect would be nullified

immediately. In actual trials, this has happened and

serious damage has been done. A driver, going up a hill,

may suddenly discover that his truck is slowing up; it

may start to roll back down the hill, gaining consider-

able momentum before he discovers that his transmis-

sion brake is useless, because his propeller-shaft or axle

shaft has broken.

It must be obvious that with the much higher relative

surface speeds of the propeller-shaft brake, the wear will

be very much greater. While the life can be prolonged

by increasing the width of the drum and the brake-band,

the cost of replacing linings frequently will be consider-

ably greater than with wheel brakes.

There have been many discussions as to which form of

drive will survive finally. Statistics show that the chain

drive practically has been eliminated. The bevel-gear

drive is increasing for light trucks and seems to be a

logical development because of its simplicity and low cost.

The internal-gear drive is losing ground and at least two

of the leading internal-gear-drive manufacturers are

building bevel-gear drives this year. The worm drive

seems to continue in its popularity, and the double-re-

duction gear is showing a fair increase. As two of the

largest builders of trucks have adopted the double-re-

duction gear recently, there is little doubt that its future

is established.

I believe that both worm-drive and double-reduction-

gear-axles have their particular use and place. Dis-

regarding the chain drive, the British manufacturers

seem to be about evenly divided between the double-

reduction and the worm drive. None of them uses the

internal-gear drive in the wheels, as shown by the statis-

tics for Tendencies in British Truck Design* for 1922,

although that form was used some years ago. It will be

observed also that a large number of manufacturers, in-

cluding Guy, Leyland, Maudsley and Pagefield, use both

the worm and the double-reduction-gear drives.

The worm drive has several advantages that put it in

a class by itself. It has a small number of parts and

general simplicity. This is only approached by the bevel-

gear drive. With a ball-bearing mounting, the rear

bearings of the worm are permanently mounted and the

front bearing is free to float. The only bearing or gear

adjustment of any kind in this form of ball-bearing

worm-drive axle is in the differential mounting, where

two threaded nuts provide the complete adjustment for

the worm and the gear. Even a bevel-gear axle requires

adjustment in another place, the pinion shaft. The worm

drive's second great advantage is its absolute quietness

in operation, which no other form of gear can provide

with such assurance of permanent satisfaction.

The double-reduction axle, consisting of one set of bevel

gears and one set of spur gears, which is used in England,

and also in this Country by Mack, Autocar and Ruggles,

has a few more parts and may develop noise if not well

made and properly adjusted. It has an advantage over

the worm gear in its wide range of efficiency. The worm

gear can be made very efficient for a given load and speed,

but not throughout an extremely wide range of loads and

speeds. The double-reduction axle has a disadvantage

compared to the worm in that it has a larger number of

parts and a few more adjustments, but this is offset by

the better distribution of the direct loads and stresses

imposed by accidental shocks; in case of failure from

any of the usual causes such as lack of lubrication, over-

load or accident, the consequential damage is less. The

side-thrust on the differential case and the mounting sup-

ports is eliminated.

The internal gear is a form of double-reduction that

involves more parts. The use of internal gears in the

wheels makes the lubrication problem extremely difficult,

and any attempt to eliminate it makes the parts less accessible and increases the cost of repairs. Some of these designs now use as many as 10 gears and 16 bearings. While this distributes the stresses and the wear, it must decrease the efficiency because every gear and bearing reduces the amount of power transmitted to the rear wheels. Furthermore, in the case of failure of some small part, the consequential damage may include several broken gears and bearings. Additional gears will produce noise and, if one gear wears unevenly, all the gears in contact must suffer.

The internal gear has claimed the advantage of lighter weight but, according to the reference previously given,[7] both worm-drive and double-reduction axles of larger capacity actually weigh less than one standard make of internal gear. The light weight in the internal gear is liable to be secured at the expense of rigid construction. In other words, an internal-gear axle may be strong enough to carry a load and transmit the power, but its flexibility throws the bearings and the gears out of alignment to such an extent that it results in noise, a short life of the gears and the bearings and a loss of efficiency. The efficiency is further reduced by the impossibility of obtaining perfect lubrication.

There have been many lengthy discussions and many fantastic claims based on the advantages to be gained by reducing unsprung weight. If unsprung weight were the sole desideratum, we should never have abandoned the chain drive. There is one claim that a 1-lb. reduction in the unsprung weight is the equivalent of a 10-lb. reduction in the sprung weight. Many engineers and salesmen using this claim do not know what this is founded upon or to what it refers. It is based on tests made by the Michelin Tire Co. many years ago, from which a conclusion was reached that the wear on the tires is increased as much by 1 lb. of additional unsprung weight as by 10 lb. of sprung weight. No reference was made to the general wear-and-tear on the vehicle, nor was the test intended to determine any variation in the fuel-consumption of the truck. Mr. Favary points out that 100 lb. at the center of the axle has less effect than 100 lb. added to the weight of the rear wheels. This brings out a disadvantage inherent in both the full-floating construction and the internal gears in the wheels. For the same total axle weight, both constructions bring a disproportionate weight directly over the tires.

From current practice, it is easy to prove that if the unsprung weight is reduced so much that the bearings and the gears suffer from misalignment, any saving in tire wear is offset many times over by upkeep and repairs on the axle itself. It has been claimed that additional unsprung weight made vehicles ride more easily, and also that the heavier axles hold the road better, so that the tires actually wear longer up to a certain point in increased axle weight. One will find automobile men to-day who avow easier riding qualities for the old-fashioned passenger-axle with transmission attached, which was an extreme example of great unsprung weight.

I believe that a reduction of the unsprung weight is desirable up to a certain point, but that it easily can be carried to an extreme. We have some definite figures on a saving accomplished by a reasonable reduction in the weight. A 5-ton axle weighing 1570 lb. was substituted under a used truck for another make of axle weighing over 2400 lb. Both axles were of the same type with ball bearings throughout; there were no radical structural differences. No other changes were made in the chassis. The test lasted 2 weeks, during which time the truck averaged 49 miles per day. There was a saving of 5 gal. of gasoline per day, which could be explained only by the difference in the weight of the rear axles.

We have some figures on the deflection of the load-carrying members that were obtained from the chief engineer of one of the leading truck companies that has used several types of axle. Three worm-axle housings of different standard makes of 1½-ton semi-floating axles were tested under static loads. The housings were supported at the wheel-bearing locations, the load was applied evenly on the spring-pads and the deflection was measured at the center of the axle. The lightest housing, constructed of pressed steel, showed a ¼-in. deflection for an 11,000-lb. spring-pad load, a ½-in. deflection for a 16,500-lb. load, a 1-in. deflection for a 21,000-lb. load and complete destruction at a 23,000-lb. load. The heaviest housing, constructed of cast steel, showed a ¼-in. deflection at 30,000 lb., a ½-in. deflection at 49,000 lb. and a ¾-in. deflection at 56,000 lb., at which point cracks developed. The malleable housing, which was heavier than the pressed-steel housing by 50 lb. and lighter than the cast-steel housing by 70 lb., showed a ¼-in. deflection at 26,000 lb., a ½-in. deflection at 45,000 lb., a 1-in. deflection at 52,000 lb. and no signs of cracking at 56,000 lb., which was the peak capacity of the hydraulic press. Remembering the effect of simple static-loads, we call attention to the necessity for sufficient stiffness to protect the bearings from the excessive deflection that shortens their life, decreases the efficiency and increases the maintenance losses. These are figures for heavy scientifically designed housings. The deflection of solid-round load-carrying members frequently is found to exceed ⅜ in. under static load equaling ordinary requirements.

It is our opinion that it is impossible to determine which form of drive will survive and whether any present design will survive, because it is impossible to forecast the tendency in engine design. The passage of laws regarding the speed of trucks may have a considerable effect on design. The tendency seems to be toward a larger number of radically different axle designs rather than toward the standardization of any one particular type.

Every axle now on the market as well as every contemplated axle, represents a compromise in which some advantageous features are sacrificed so that the designer can incorporate features he believes to be essential. No engineer would use a solid-round load-carrying member except to reduce the cost of the rear axle. We might recommend the overhead worm-drive for bus service, if the desire to lower the floor-boards did not militate against it. If the bus builder insists on the lower floor-board design, he must either invert his worm-drive axle or use another form of rear axle. Inverting the worm has three serious disadvantages; it (*a*) reduces road clearance too much; (*b*) calls for too great an angle on the propeller-shaft; and (*c*) results in poor operating conditions, inasmuch as sediment has no chance to settle in the bowl and constantly runs through the worm bearings and over the worm-gear surfaces. The same trouble is experienced with internal gears, because no sediment or grit can settle to the bottom of a chamber but is continually circulated around in the lubricating medium, thus destroying the gear surfaces and the bearings.

It might be well to point out that the extreme angle of the propeller-shaft cannot be corrected by tilting the rear axle, as is occasionally attempted, without introducing a serious complication. If the transmission shaft and the

[7] See *Automotive Industries*, Feb. 16, 1922, p. 388.

transmission-shaft or live-axle shaft are parallel, the harmonic motion introduced by one universal-joint can be offset by the second. If the rear axle is tilted, the harmonic motion is transmitted and a short life of the bearings and the gears will result, with possible additional damage to the engine.

The axle designer who believes he has perfected the one satisfactory type is reckoning blindly. One of our engineers is producing a satisfactory steam truck. Others are experimenting with very interesting new types of engine. He would be very rash who would attempt to forecast the developments of the next few years. The progressive manufacturer will encourage designers to work diligently, because there is always room for improvement. If any present design is perfect, the reduction of cost provides considerable material for study. If the first cost of all types of axle were the same for equal capacity, several types now purchased because of their low first cost would disappear in an extremely short time. As both the worm-drive and the double-reduction types are high in first cost, and both have increased in production while other designs have decreased, we can consider that they will continue in use until something better shall be designed or something equally good produced for less money.

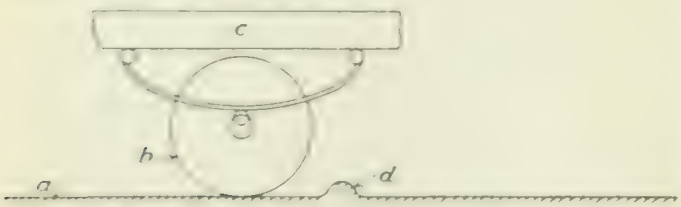


Fig. 36—Diagram showing Relation between Sprung and Unsprung Weight when a Wheel Strikes an Obstruction in the Road

Mr. Favary:—The best proportion of unsprung weight is a very interesting topic. We sometimes hear that the unsprung weight should be just so much, but not less. Suppose a road surface *a*, as shown in Fig. 36, and that we have one small unsprung weight *b* below and a heavy weight *c* above. There is a spring between the unsprung weight and the sprung weight. When the unsprung weight, which is carried by the wheel, moves over an obstruction *d*, it will be propelled upward with a certain velocity. The velocity and the acceleration will vary, but assume that the maximum velocity is attained when the wheel reaches the top of the obstruction. The unsprung weight will have a certain amount of kinetic energy which will propel it higher up, and this kinetic energy will be imparted to the unsprung weight above, through the spring. It is evident that the heavier the unsprung weight is, the greater will be the kinetic energy and, therefore, the upward thrust, even after the wheel leaves the obstruction, will be greater. On the other hand, if the unsprung weight be little or if we assume first that the unsprung weight has no weight, the sprung weight resuming the same the unsprung weight, not having any kinetic energy, would follow the contour of the obstruction and come to the ground immediately after the wheel left the obstruction.

In practise, the unsprung weight must have some kinetic energy, the amount depending on the speed and on the mass that is thrust upward. Hence, the greater the kinetic energy is, the more the body will be moved upward, and the greater will be the shock imparted to the unsprung weight.

Alfred F. Masury:—I disagree with Mr. Myers on the matter of standardization. I do not wish to fight the war over, but we all know the story of the Hispano-Suiza engines that did the work while we, in this Country, were frantically standardizing. I think we all know also that the Peerless, the Pierce-Arrow, the Mack and the Four-Wheel-Drive trucks were doing the work at the front while we were trying to standardize Class-B truck-axles. We ought to keep away from the standardization of axles. One of the truck-axle designers has said that there will be many more different types of axle, and I think that will be true.

If we look at the passenger-car companies, the ones that have had the least standardization probably have been the most successful. The Ford, Dodge, Franklin and Stanley steamer companies have gone through this trying period with flying colors, making money. Considering the truck companies that have gone through this period without actually losing millions of dollars, such as the Autocar, the International Motor and the Fifth Avenue Coach companies, I think we can say that any one of those companies has had less standardization than some of the organizations that have lost as high as $8,000,000 in 1 year; so, I think it is fair to say that we should keep away from axle standardization, except within certain limits.

On of the new things in the motor-truck industry at present is the rail motor-car. There is hardly a large truck organization that does not have some form of rail motor-car running on the railroads. The railroad engineers as a whole are one of the best educated and most highly trained class of engineers we have. Why did they not build rail motor-cars? Simply because they are surrounded with the Master Car Builders' Standards. We do not want the Society to become a mass of standards that will take the initiative out of its engineers. Therefore, I think it is fair to say, we will not get all the motor-vehicle axles alike.

Shall we take the initiative out of this Country and the opportunity of each engineer to express his notions, even though some of them may be bad? I believe we are doing harm when we say that we should standardize anything as important, and on which the industry has as many things to learn and do, as rear-axle design. As an illustration, when the Pierce-Arrow company first came out with its worm-drive axle, it certainly did prosper on that axle and on that whole truck, which was entirely different from anything we had seen in this Country. We could go on citing cases almost indefinitely. Of course, a man must be right to a reasonable degree and be fairly good as an engineer, have a good organization back of him, a good manufacturer and good materials; but if a man believes in some particular type of design that can be based on good engineering, we should do nothing to hinder him in expressing those ideas.

I would like to add that the company with which I am associated built worm, chain and double-reduction axles and made tests of these three types of axle. We used three trucks, had the engines governed alike and changed drivers. We made five different types of test. In one, we started the trucks moving and let them coast; in another one, we ran them up a grade to see how far they would go before getting into second speed; in a third, we started them all on a hill and noted how fast they would go up to a certain point; in a fourth, we backed them up to a curb to see which one would climb over the curb; and in the fifth test a dynamometer recorded the number of pounds that each truck could pull. In each of

these tests the chain drive showed the best; then came the double-reduction and then the worm drive. I think that is perfectly easy to explain. We have more surface and contact and thus better lubrication; and I think that is the whole story.

I want to mention one other thing. I think the best spring-shackle is Mr. Myers' design but, supposing that spring-shackles had been standardized, we never would have had the wick lubrication that he has worked out very satisfactorily on many trucks.

MR. MYERS:—Mr. Masury cited two or three car builders as examples of manufacturers who did not standardize. I have no desire to limit the initiative or originality of any engineer and, in that matter, I am sure the S. A. E. Standards policy coincides. There are many inconsequential details in axle construction that should be standardized. When we have enough experience on units that we may be building to say what is good practice and what is poor practice in regard to its details, let us stop making variations in those details that simply call for additional sets of spare parts in every service-station in the Country. Such practice is not logical.

Mr. Masury cites the Master Car Builders' Standards. There is no better exemplification of the good that could come to a transportation industry than those very standards. The reason that railroad cars can be built so cheaply, serve us so well and run great distances from their place of origin is that, even when a railroad car has run this 1000 or 2000 miles from home, the service-station car-shop to which it happens to be sent for repair has parts that will fit, all made to the Master Car Builders' Standard specifications. If the railroads are reaching out to obtain cars propelled by gasoline, not having conceived that idea themselves, since they were endeavoring to perfect their own type of apparatus, they very naturally reach over into the automotive industry and pick out what they think will be of use to them. In Mr. Masury's specifications for his rail motor-car, I notice that he specifies that the front trucks are to be built to the Master Car Builders' Standards. It is futile to argue this question of standardization again, because we all know the good that has been accomplished already and it has yet to be shown that standardization has limited initiative or cramped design.

The value of unsprung weight has been discussed in this Country for about 18 years, with reference to automobiles. So far as I know, there is no evidence to substantiate any such faciful ratio as 5 to 1, 7 to 1, or 10 to 1, for the weight below the springs to the weight above the springs. For more than a year I was in fairly close touch with a test made by a very large truck operator in one of the metropolitan cities. It is described in my paper. Notes on Motor Trucks.[3] Four trucks of about the same load capacity were used. It was discovered that the tire mileage was greater on the two worm-drive trucks than on the two chain-drive trucks. The unsprung weight on the worm-drive trucks was 70 per cent in excess of that on the chain-drive trucks. The load per inch of tire width on the chain-drive trucks was about 6 2/3 per cent in excess of the corresponding load on the worm-drive trucks.

Leaving out all questions of unsprung weight, one would naturally expect that the wear on the tires for the worm-drive trucks would be somewhat less, in that they were loaded a little less per inch of tire width. We might expect 10 per cent more tire wear on the chain-drive trucks. The actual difference was about 31 per cent in favor of the worm-drive truck. But this does not prove that the heavy axle is better than the light axle.

We all appreciate that theories help us to solve problems, but we do look for some substantial tangible results, something we can define as actually having saved us money somewhere. I think Mr. Favary should have gone somewhat further with this subject. He says that the impact of the unsprung weight on the vehicle load, with the heavy axle, will be greater than that with the light axle. That may be true, but it is not in direct proportion, much less a ratio of 5 to 1 or 7 to 1. The tire must and does absorb much of the shock due to the greater inertia of the heavier axle. From this it is inferred falsely that the tire must wear more. But I have never been able to find out that this greater weight affected the tire wear to any substantial extent, and I have checked it since the time when we were first able to get records on the worm-drive trucks versus chain-drive vehicles. In 1912 and 1913 I could not find that the tire wear on the Pierce-Arrow worm-drive trucks was any greater than that of the Packard or any other chain-drive trucks in use at that time; in fact, what data were secured pointed the other way. We need more information on this subject of unsprung weight. It is not fair to make assumptions and statements concerning unsprung weight unless there is substantial evidence with which to back them up.

MR. MASURY:—Mr. Ford and Mr. Dodge have their own standards, and not those of any outside organization. With regard to the standards on the railroads, they are not particularly attractive as to the working out of cheap transportation when judged by railroad earnings.

A. G. HERRESHOFF:—The Fifth Avenue Coach Co. employs both worm and internal-gear axles for its coaches. This company commenced operation with DeDion chassis. The axles were of the internal-gear type, the differential assembly being bolted to the chassis frame and therefore constituting sprung weight. No mention has been made of this character of axle.

In 1915, the Fifth Avenue Coach Co. commenced the production of its own equipment, known as type A; the rear axles were worm-driven. In 1918, a second type was evolved, the type L. These vehicles are hung very low and internal-gear axles are used.

Of the different types of axle above mentioned, there is the least unsprung weight with the DeDion; next comes the type L, the heaviest being the type A. It is rather difficult, however, to give any correct data in regard to the relative tire-wear. Naturally one would expect the best results with the axles showing the least unsprung weight. But it will be realized that the development and employment of these axles has been spread over a long period and during this time many improvements have been made, particularly by the tire manufacturers, the net result of which is that the Fifth Avenue Coach Co's. tire mileage to-day is much greater than it was when the DeDion vehicles were in service.

DR. H. C. MCBRAIR:—Mr. Favary stated that one should not use a reduction of greater than 6 to 1, but I believe that it is perfectly possible to go to at least 9 or 10 to 1 with spiral bevels; in fact, he shows the spiral bevel with a six-tooth pinion.

The double-reduction axle seems to be the coming type. It ranges from vertical to 90 deg. from vertical. What is now needed for efficiency is a good two-speed axle of simple construction and low cost, that can be made for a chain, an internal-gear or a double-reduction drive. This would give four speeds, which would include an extra low and an extra high, with only a low and a reverse in the

[3] See THE JOURNAL, October, 1922, p. 333.

gear-box. An axle of this kind should increase the tire mileage by 50 per cent and also would reduce the repair bill. It would allow a full load to be carried over good roads on the extra-high gear with only one-half the engine speed and would carry the same load over ordinary hills or heavy roads on the regular high-gear, thus eliminating the power losses in the gearbox.

In reference to the axles for railroad work, an axle is made by the Wisconsin Parts Co., of the double-reduction type that has two bevel-gear rings and one pinion. This axle gives the same speeds forward or reverse. Another type has three speeds forward and a reverse, all direct, but a chain drive. In the car, the engineer, who was not an automobile engineer, placed his powerplant on the truck, thus providing a drive-shaft less than 6 in. in length.

In passing with railroad men, I find that they all criticize the car that is made from a truck design. They say that the axle is too far from the powerplant and that, with a Hotchkiss drive or radius-rods on an ordinary truck, the two wheels on the rear axle have a tendency to follow a siding or switch if the latter is on the outside of the curve because the weight of the car and its passengers throw the axle out of alignment in the wrong direction. One railroad official has refused to allow such two-wheeled axles on his road, but he has allowed the four-wheeled truck.

MR. FAVARY:—Referring to Mr. Myers' remarks about unsprung weight, if the load is the same, that is to say, the sprung weight, the engine power and the springs, then the lighter unsprung weight will be more advantageous. Unless we have the exact data under the conditions named by Mr. Myers, we cannot consider two trucks, one perhaps running at a much greater speed than the other, or one having better springs than the other, as a criterion; but, if all of the conditions are alike, save the unsprung weight, I maintain that the unsprung weight will affect the riding quality and the wear of the tires in direct proportion to its lightness. Nothing that I have heard so far would make me change that opinion.

Regarding Dr. McBrair's remarks on the limit of reduction of 6 to 1 for the double-gear drive, I simply said that, ordinarily, we find that the limit of the reduction of bevel-gear drives is 6 to 1, but I believe this will not remain the limit, nor do I think that the final word has been said on any one of these different types of axles, including the internal-gear-drive axle. We are looking forward to many improvements.

R. L. FIELDER:—The coaches with axles such as Mr. Hemstead has referred to were in operation between 1907 and 1913. Approximately 160 of these vehicles were used in all. It is interesting to note that our average tire-cost taken over this period was 3.36 cents per mile and that the present figure is 0.86 cents per mile. There are, of course, many reasons for this decrease; for example, better tire manufacturing methods, improved vehicle design including decreased weight, and particularly steering gears, the standardization of metal wheels and, last but not least, closer operating and repair supervision.

Obviously, the unsprung-weight factor is very important, from the standpoints of tire and of road wear; and if we lose sight of the latter, we may soon face heavy taxation as a direct result, particularly bearing in mind the unquestionable possibility of a much more general use of the heavier types of motor coaches.

Mr. Hartman has stated that with solid axle-shafts of large diameter, difficulties might be expected in connection with heat-treatment. We have not found this to be the case. The axles of all our type-A coaches are of the semi-floating type. The drive shafts are of large size. They are made from 3.5-per cent nickel 0.40-per cent carbon tubes. Parallel tubes are cut to suitable lengths; then the ends are swaged taper. This construction has worked out exceedingly well, and so far no failures have been experienced. It should be mentioned that this type of drive-shaft is approximately 66 lb. lighter than the original solid-shaft design.

From the standpoint of the large operator, it is highly desirable that wheels be readily removable. The ideal is to be able to take off a wheel without disturbing any other part. In cases where it is necessary to remove the bearings and the like, there is always a possibility of the introduction of dirt or other foreign matter, and great care must be exercised in connection with the reassembly and adjustment. Generally speaking, it is necessary to remove wheels during the inspectional period and also where the tires require renewal. The process of wheel removal should be made so simple that it can be carried out safely by the most unskilled type of workman.

Referring to Mr. Favary's remarks in connection with the unsprung weight, certainly we dislike weight in any form; but we believe that weight at the center of an axle is less harmful than at its outer extremities, that is, at the wheels, for it is seldom that both wheels of a vehicle make contact with a bump or depression at the same time. Usually, one wheel only is affected. Assuming for example, that one wheel mounts a ridge 2 in. high, the movement at the center of the axle will be approximately 1 in.; therefore, the kinetic energy in the mass will be less if the bulk of the weight is located at the center of the axle than if its location were at the outer extremities.

MR. MASURY:—How much mileage has the axle of the newer internal-gear type made? How has it worked?

MR. FIELDER:—Our type-L coaches, which are equipped with internal-gear axles, are being operated in New York City, Detroit, Baltimore and Pittsburgh. The largest operation is in Detroit where there are approximately 70 of these vehicles, the majority of which have done 18 months of service or more. Quoting recent figures, the lowest mileage of any coach is approximately 40,000 and the highest approximately 80,000. According to official statements issued by the Detroit Motorbus Co., exceedingly good tire-mileage is being obtained, this being at least equal to that in our own operation here in New York City.

MR. FAVARY:—I believe we must discard everything we know so far as tire mileage of a few years ago is concerned, when we make a comparison with present-day tires. As Mr. Fielder has indicated, the tires are different to-day; the quality of the tires is very much different from what it used to be.

Lighter unsprung weight does not damage the road so much. The two are interrelated because, the heavier the blow against the road surfaces is, the heavier the blow against the tire will be. However, here also we can make no comparison unless we have tires of the same quality.

SAMUEL H. WOODS:—We have heard very little about axle housings. In the dual-reduction axle housing, we are using a single drop-forged member. In so doing we are naturally getting the benefit of material that has been pretty thoroughly worked as compared with a cast or built-up structure. Also, we are able to forge on the spring-saddles, thereby getting away from the weakening effect of attachments by riveting or other means. In the same axle, due to our peculiar carrier construction, we

have extreme accessibility not only of the entire differential carrier, but of its various components. For instance, we can remove the pinion and bearings or the countershaft and its bearings. In that way we can change the gear-ratio very easily.

CHAIRMAN H. W. SLAUSON:—The construction to which you refer is covered in Mr. Favary's paper by a short description.

M. C. HORINE:—I think Mr. Woods' point is that Mr. Favary did not cover what we call the banjo construction. A peculiar feature of construction is that the banjo is placed at an angle of 45 deg. instead of being vertical, as in an ordinary passenger-car axle; it inclines forward at the bottom. There are some very good reasons for that arrangement. First, it provides greater strength. We know that the shocks from the road are not vertical but, because of the forward motion of the vehicle and the shocks that are received from obstructions on the road, the forces acting on the axle are a combination of horizontal and vertical components which are resolved into an angular thrust. Of course, the strength of the banjo is greatest through it, instead of across it. Another advantage is the increased road-clearance. The revolving of the bottom portion of the banjo yoke toward the front raises it at the same time and, at 45 deg., it happens that the lowest portion of the banjo is just about on a line with the lowest portion of the large ring-gear or bull-gear. A further advantage that comes from the 45-deg. angle is that we are able to obtain greater top-clearance. Top clearance is becoming of greater importance, owing to motorbus development that requires a low flooring. Because of the second and third advantages, it is possible to use a larger size of banjo, a larger banjo-ring. This is one means of getting greater strength. Another advantage in the 45-deg. angle is that the spur-pinion or jack-shaft can be located anywhere that is convenient. This enables the bevel-pinion center to be located exactly at the height from the ground that the crankshaft occupies under full load, thereby securing a straight-line drive. This also has its effect on the universal action, because the nature of the deflection is a combination of fore-and-aft and angular deflections; so, we get approximately equal slip-joint and angular action as against a greater proportion of slip-joint action in a vertical banjo, and a very much greater angular deflection on the type of axle where the spur-pinion shaft is located immediately in front of the differential, therefore bringing the bevel pinion at a lower elevation.

The 45-deg. angle also greatly facilitates the removal and replacement of the carrier, which is sometimes necessary in double-reduction and worm-drive axles. If the banjo were horizontal, it would be necessary to lift the carrier vertically. There is usually a lack of top clearance under a truck body for this operation, which requires the removal of either the body or the axle from the truck. It is also difficult to line-up the banjo or axle-bowl studs with the holes in the carrier flange when the carrier must be lowered straight down. If it were vertical, as on passenger-car axles, the carrier would have to be drawn straight forward and the studs lined up by lifting vertically. This is even more difficult. The 45-deg. angle decreases the amount of vertical lift by half, and makes it possible to remove the carrier without disturbing the load, the body or the attachment of the axle to the chassis. In replacing it, the studs are lined up with the holes in the carrier flange without difficulty, since their angular relation permits them to be lined-up by merely swinging the unit.

Another effect of that arrangement is that the weight of the carrier is carried slightly ahead of the central line of the axle, thereby throwing the axle out of balance statically. That is of advantage because the driving or torque reaction tends to cause the axle to revolve backward. If it is out of balance in the forward direction, the two unbalances tend to neutralize each other and we get less torque-reaction on the spring, or on the torque-rod, than if the axle were in static balance.

It is worthy of note that the development in axle splines has shown the advantage of using the raised type as against the more conventional undercut type. It is well known that a spline, or any form of channel that is cut in a piece of steel, reduces its strength approximately to the strength of a section whose diameter is across the smallest part of the shaft. If the splines are raised over the diameter of the shaft, then the strength at the splines is increased.

We have assumed, thus far, that double-internal brakes are a good thing. But let us examine them for a moment. The reason we have two sets of brakes is to enable us to alternate them, thus allowing one set to cool-off when overheated while the other set is applied. It is the brake-lining that burns, but it is the drum that becomes incandescent. The brake-lining will cool-off almost instantly, but it takes time for the steel drum to cool. If the first set has heated the drum so hot that it burns the lining, applying a second brake to the same red-hot drum will not only prevent the drum from cooling-off, but will cause the second brake to burn almost immediately, whether it be side-by-side with the first set, on the other side of the same drum or in any other arrangement.

It is therefore desirable that the two sets of brakes act on entirely independent drums. On one type of axle described here in the paper, there are two drums, one within the other. The objection to this arrangement is that the necessarily restricted space makes it impossible to use brakeshoes sufficiently large for truck work. Furthermore, the inner drum is reduced to a diameter too small for effectiveness and is prevented from radiating its heat properly. The only thing left, therefore, is either a shaft-brake or a front-wheel brake. I think we are not prepared to change to front-wheel brakes; so, we have nothing left but the shaft-brake. In regard to the much maligned shaft-brake, it is not fair to criticize a construction because of the failure of certain examples of that construction. In some cases it has been used very successfully. A shaft-brake has the advantage that it is unaffected by the spring action. It is a very common experience with rear-wheel brakes that, when locked by the hand-lever when the truck is left unattended, spring action results in loosening the brakes. I had a car several years ago that had that defect. If I applied the brake while sitting in the car and then got out of it, the spring rebound would release the brake. It was then necessary to apply the brake two notches farther before it would hold the car on a grade. That is an extreme case, but it indicates the presence of such an effect. We know that motor-truck springs are much more affected by the load than those of passenger cars. The shaft-brake is the only one not affected by the spring deflection or the Hotchkiss-drive reaction; also, it is the only equalized brake possible because, while one may equalize the pressure applied to two brakes, one cannot equalize the traction of the two wheels on the road except through the differential.

MR. HERRESHOFF:—What was the foot-brake on the car Mr. Horine mentions?

MR. HORINE:—That shaft-brake was operated by the foot. I believe that is not the ideal way to operate a shaft-brake. I think the hand-lever is the proper means of application. That particular brake was improperly designed. It did not work well because it was really not on the frame of the vehicle; it was on the pinion housing of the axle. The result was that the reaction from the torque caused to release the brake. If a shaft-brake is mounted on the frame, one will not get any such effect. Much of the criticism of shaft-brakes is based on experience with types that were inclined to be savage or to chatter badly. Drivers of a number of cars that were equipped with this type habitually used the hand-lever, connected with the rear-wheel brakes in preference to the pedal operating the shaft-brake. The trouble with these brakes was that the drum and the shoes were improperly supported. The drum was usually secured to the tail-shaft of the transmission, so that it overhung the rear transmission-bearing, the shoes being supported separately by pins screwed into the transmission case. The result was that the drum did not run true and the shoes were deflected by the sudden strains put upon them. This had the effect of rapidly applying and releasing the brake. No wonder it chattered. These things cannot happen when the brake-drum is supported between two bearings, with a universal on either side and the entire brake assembly, including the bearings for the drum shaft, brakeshoes and actuating means are supported on one rigid carrier.

MR. MASURY:—Will Mr. Fielder describe the rear axle of the internal-gear type that is built for the Detroit buses?

MR. FIELDER:—The rear-axle construction of our type-L coaches, a number of which are operated by the Detroit Motorbus Co., is rather unconventional; for example:

(1) The carrying member is a heat-treated forged job. In this way we are able to obtain material with absolutely uniform properties and also there is a wide range of choice. Full advantage can be taken of alloy-steels and proper heat-treatment. Naturally, the use of high-grade material permits the use of minimum sectional or wall thicknesses, and this is a very important factor from the standpoint of weight reduction

(2) The ends of the carrying members are cranked, the wheel spindles being located above the drive-shaft center-line. This construction permits an extreme low level

(3) The design of banjo is such that it is inclined at an angle corresponding to the path through which the brake reactions must pass. In this manner the extreme fibers in the housing material are distributed in the direction of the greatest stresses

MR. MASURY:—Naturally, the Fifth Avenue Coach Co. is not limited by any particular type of axle. If it sees fit to give up one type of axle, it can use a built-up or a unit axle. It is interesting to hear from a company that is entirely unbiased as to the type of axle it builds or uses.

C. C. KAWEIN:—Is it not true that the worm-gear drive lasts longer than any of the other types of axle that have been mentioned?

MR. FAVARY:—I do not see why the double-reduction axle cannot be built to last just as long. I know of worm-gear axles that have given very good and of others that have lasted a very long time. It simply depends upon the amount of pressure to which the worm is subjected; if the pressure is not excessive, the worm will wear a long time. If the pressure is excessive or if the lubrication should fail, the worm drive may be damaged within a very short time. Ordinarily, it does not fail in a short time.

FINLEY R. PORTER:—In discussing the difference between rear-wheel and propeller-shaft brakes, no stress seems to have been placed upon the relative amount of work performed by these two brakes. In trucking, where the loads are excessive, this should be a very important matter. I do not know why the propeller-shaft brake is not used extensively as a service brake instead of the rear-wheel brake.

MR. FAVARY:—There is no doubt that the propeller-shaft or transmission brake has a number of advantages. On the other hand, the disadvantages are that the torque is greater in the axle-shaft, as well as in the propeller-shaft and the gears; therefore, when a propeller-shaft brake is employed, heavier shafts and heavier gears must be used to obtain the same factor of safety and hence the construction will be more expensive. Regarding the difficulties experienced by Mr. Horine with wheel brakes, if the brake linkage is correctly designed these objections are practically overcome.

MR. MYERS:—I do not want to be interpreted as wishing to add weight to unsprung parts. Everyone strives to reduce the weight of the axle parts to a minimum; that is very important. But I do wish to reiterate that the matter of tire wear being in proportion to the unsprung weight has by no means been proved. There are varying conditions in almost every case which entirely nullify any data that I have ever seen on this subject.

In regard to the tire mileage on wood wheels as compared with that on steel wheels, the test on unsprung weight that I referred to was really to check-up the advantage of one wheel over another. We used four trucks to get an average of 24 tires. We put a wood wheel at the right side of one truck in the front and at the left side in the rear. On another truck, we put the wood wheel over on the other side, so that each front axle had a wood wheel and a steel wheel. The entire advantage in winter and summer performance was about 15 per cent in favor of the tires on the wood wheels over those on the steel wheels.

MR. FIELDER:—We have had tires from the same tire company some of which were returned for credit because of not doing their guaranteed mileage, but others in the same batch would do five times their guaranteed mileage. One cannot tell whether a tire is cured properly or not. It may be that different qualities of tire were used in the tests Mr. Myers mentions.

MR. MYERS:—The tires were all made at about the same time from the same batch and received the same curing. They were inspected carefully; the comparison was so close that we could not detect any difference. I will admit that there may have been some differences in the tires, but we took care to minimize them. It is remarkable that the rate of wear on each truck was different, and the rate of wear on the four tires on each truck was grouped, showing that the tires must have been very nearly of the same composition.

MR. HORINE:—From that test we may at least assume that Mr. Fielder's mileage experience with tires was not very much affected by whether the wheels were wood or steel; so, the decreased unsprung weight must be the explanation of the better tire wear one gets on the lighter axle.

MR. MYERS:—But the results show that there was less tire wear on the axles with the greater unsprung weight.

MAURICE WALTER:—The wood wheels are probably much different in weight compared with the steel wheels, and their inertia effect is probably enough greater to give an unbalanced differential action. In the ordinary truck there is a certain differential action, but if one wheel has a greater inertia than the other, there will be an unequal differential action and the tire wear will be entirely different from that of normal conditions.

MR. FAVARY:—Inasmuch as Mr. Myers agrees that it has not yet been proved or disproved in practice that a light unsprung weight is favorable, which I maintain, I think we ought to assume that the theoretical proofs are correct until practice proves them incorrect; that is, a lighter unsprung weight is more favorable.

MR. MYERS:—I cannot accept that, because such evidence as I have obtained is contrary to it and I prefer evidence to theory.

MR. HORINE:—Mr. Rockwell mentioned the proportions of worm-drive and double reduction axles in use in England and prefaced his remarks by saying, "Disregarding the chain drive." I think it is not fair to disregard the chain drive in England. They have been building trucks longer than we have and they redesign their trucks more frequently than we do. It is very interesting to notice the number of new heavy-capacity trucks in England, post-war models, that have been brought out with chain drives. The chain drive is on the increase in England.

In regard to the quietness of the worm drive, it has been said again and again that a quiet machine is an efficient one, and that friction always produces noise. That is a fallacy which is accepted at face value and in many cases without question. Yet a worm-drive axle is always quiet, whether it is producing friction or not. I have seen worm-drive axles so badly bound-up in their bearings and on their worm surfaces that they would stall the engine, and still they were quiet. The chain drive is very much maligned because it is noisy. I believe that the noise of the chain drive is one of its greatest virtues, because it tells a story. Ingenious inventors develop devices to notify us that certain parts require attention. A chain drive is an inherent alarm. Under proper conditions, it makes some noise, but when it becomes worn or out of adjustment to a dangerous extent it gives an audible warning which the worm drive does not give. That warning is sufficiently in advance, in many cases, that it is perfectly safe to run for two weeks or more with the chains in that condition, and one can change the chains or sprockets at his convenience.

Much of the present conception of the chain drive is based upon past experience. Most of our manufacturers have not had any recent experience with the chain drive and, while they have been developing various other types of drive, the development of chain drives has gone on and some very genuine improvements have been made. Among them are case-hardened front sprockets, very much larger sprockets, more moderate reductions in the chains and better radius-rod construction. Radius-rods that are attached to frame fittings instead of to jackshafts and radius-rods that are in line with chain centers and therefore give less chance for springing the axle and jackshaft together have been adopted.

Concerning bevel-gear reductions, Mr. Favary has specified 6 to 1 as a limit in the present state of the art. It is possible to get a very much lower reduction than that, but it also is a fact that the amount of gear reduction one can get depends upon the amount of load that is being transmitted through these gears; the greater that load is, the less reduction one can use because of the physical limitation of size that the vehicle imposes. It is fair to say that on a very heavy truck the maximum is 4 to 1, and on a light passenger-car one might use a greater reduction than 6 to 1.

MR. FIELDER:—What mileage can be expected from the rear-wheel driving-chains? And what is the cost of replacing the chains? It seems to me that chains exposed to the grit and dirt of the roadway could not last very long.

MR. HORINE:—Normal chain-drive mileage is somewhere between 18,000 and 21,000 miles in regard to the life of the chains. The life of case-hardened front-sprockets is approximately twice that of the chain. The rear sprockets never wear out. The front sprocket can be reversed at the time of the first chain renewal. The cost of a chain is as much as $85 for a large truck. In comparing the cost of chain replacements, it should be borne in mind that the age of the truck has nothing to do with it. The cost of worm replacement during the period of truck life is along a curve that has its progression from left to right and moves upward.

C. W. SPICER:—The extra weight or extra strength required with the propeller-shaft brake has been cited against it. That is properly justifiable in theory. However, after fifteen years of specializing in propeller-shafts, I cannot say that, in practice, there is any more evidence of wear in the propeller-shaft when the transmission brake is used than when there is none.

MR. FAVARY:—Does Mr. Spicer refer to light cars and trucks, or to heavier trucks?

MR. SPICER:—I refer to either size.

MR. FAVARY:—Then I disagree with Mr. Spicer, because we find in the example I have taken that if a propeller-shaft brake had been used, the maximum torque due to braking would have been about 97,000 lb. in., whereas that due to the engine is about 65,000 or 66,000 lb.-in.

MR. SPICER:—The maximum-torque stress on the propeller-shaft due to the transmission brake is that which is required to slip the tires on the road. The shafts should be designed to slip the driving-wheels under any condition. The total number of hours of life of a car during which load is applied to the propeller-shaft through the transmission brake is so small and the periods of application are so short that the reduction in the life of a properly designed propeller-shaft due to transmission braking has been found to be negligible. My comments are based entirely on long experience rather than on theory.

MR. FAVARY:—I cannot see how the dropping of a full-floating axle into a hole can make much difference in regard to the torque. I still maintain that a transmission brake will put a higher torque on the shafts in heavy trucks. We find in practice that it is not possible in heavy trucks to slip the wheels with the engine power on dry roads; whereas, when a propeller-shaft brake is employed, the torque created from the slippage of the wheels is considerably higher than that arising from the engine.

MR. MASURY:—I think Mr. Favary and Mr. Spicer are both correct. The real difficulty with propeller-shaft brakes is not with the brake itself but with the element of allowing a dead or a nearly dead engine to be picked-up by the car's momentum. This occurs in trucks and large cars after driving down a long hill. The car gains considerable speed and the drive-shaft is running very fast; the energy necessary to accelerate the engine often throws out the drive-shaft. This is far in excess of any

strains which may be imposed on the propeller-shaft by a propeller-shaft brake. I believe that the great advantage of the equal distribution through the differential and the rear axle of a breaking effort, far overcomes any disadvantage. It also leaves the brake-drums on the rear wheels much less work to do and relieves the "spinning" action and the heat distribution.

The great difficulty I have had with propeller-shaft brakes was due to their being improperly designed. Since we reached the point where we encased the brake mechanism in a frame, put bearings on the outside of it and had the brakeshoes properly disposed, the propeller-shaft brake certainly has been very successful. It is much better than the other types in getting rid of the heat from the brake-drum. When you get down a long hill, your brakes will be so hot that you can spin them out-of-round. It is a question of not letting those brake-drums get warm, so they cannot distort with the heat and with the spinning action of the brakeshoe.

I would like to bring up the question of torsion shafts on the rear axle. The particular shaft I have in mind can be twisted around three times. We have attached considerable importance to the fact that the propeller-shaft can move around in torsion. As was pointed out, the greatest strain is torsional and, if we use this as a spring, we soften down the action of the drive and the propeller-shaft brake, which cannot be done in a semi-floating axle, because it will not be possible for it to get into a torsional action. One of the great things in favor of the full-floating axle is that the propeller-shaft is alive.

STANDARDS ADOPTED BY LETTER BALLOT

THE proposed standards and recommended practices [illegible] to 585 inclusive of the June, 1923, issue of THE JOURNAL and approved at the Standards Committee Meeting at Spring Lake, N. J., June 19, were approved by the Society members by the letter ballot that closed on July 21. The new and revised data sheets containing the recommendations approved were mailed to the members during August, practically within 2 months of the time they were approved by the Standards Committee and more than a month earlier than former issues have been mailed. This was due to the fact that the revision in the Standards Committee Regulations requiring the letter ballots to be returned 3 weeks after publication of the Standards Committee report in THE JOURNAL, instead of 2 months after the Society Meeting, was authorized by the Council at Spring Lake.

The complete vote of all the recommendations balloted upon is recorded in the accompanying table. The first column gives the number of affirmative votes cast; the second column, the number of negative votes and the third column, the number of members who did not vote either way.

Subject	*Yes*	*No*	*Not Voting*
Timing Belts and Pulleys	84	0	218
Front Wheel Mountings	12[illegible]	[illegible]	17[illegible]
Truck Hubs for Steel Felloes	109	2	191
Metric-Type Thrust Ball-Bearings	142	9	151
Metric-Type Roller Bearings	145	5	152
Shaft and Housing Fits and Tolerances for Ball Bearings	155	5	142
Rubber Bushings	145	1	156
Clips	151	0	151
Cable Terminals	153	0	149
Starting-Motor Mountings	149	1	152
Battery Trays for Electric Trucks	74	0	228
Charging-Plugs and Receptacles	74	0	228
Electric Vehicle Motors	69	0	232
Carbureter Flanges	153	1	148
Passenger-Car Frames	129	0	173
Iron and Steel Specifications Part IX	184	2	116
Iron and Steel Specifications Part X	182	2	118
Bases, Sockets and Connectors	135	1	166
Radiator Nomenclature	144	0	158
Brake-Lining	152	1	149
Rod-End Pins	153	1	148
Cotter-Pins	168	0	134
Felt Specifications	140	1	161
License-Plates and Brackets	156	0	146
Taper-Fittings with Plain or Slotted Nuts	158	0	144
Motor-Truck Cabs	93	2	207
Stationary-Engine Crankshafts	76	0	226
Stationary-Engine Belt-Speeds	74	0	228

FIRE HAZARDS OF AUTOMOBILES

IN writing on this subject in a recent issue of the *Eastern Underwriter*, G. D. Becker, assistant engineer in the casualty department of the Underwriters' Laboratories, points out that in analyzing the inherent hazards of an automobile when considered under general groups that can be applied to any automobile, several main items must be given attention. These are the storage of fuel, the fuel-feed system, the fuel line and fittings, carburetion, electrical equipment, the exhaust system and miscellaneous items. The method employed by the Underwriters' Laboratories in analyzing automobiles from the fire hazard viewpoint is outlined below.

STORAGE OF FUEL

Capacity of Tanks.—Not less than 10 gal. nor more than 35 gal.

Location of Tank.—At rear of car and not enclosed in body

Construction of Tank.—Strength of materials and design of tank

Tank Mounting.—Mounted to prevent chafing and excessive wearing of frame being transmitted to tank

FUEL-FEED SYSTEM

Gravity.—Pressure-release valve provided

Pressure.—Construction of vacuum tank

Vacuum.—Location of vacuum tank

FUEL LINE AND FITTINGS

Tubing and Connectors.—Tubing annealed, seamless and "non-corroding" material
Tubing suitably secured at all points to prevent chafing and protected from injury
Feed line above road clearance

Gages and Reserve.—Quantity indicator of suitable type provided and correctly installed
Reserve section provided in main supply tank

Shut-Offs.—Shut-off valve provided to shut off supply of fuel from storage or vacuum tank to carbureter.
Shut-off operable from driving compartment

CARBURETION

Design of Carbureter.—Eliminating excessive back-fire due to improper carbureter design

Location of Carbureter.—Located remote from spark or flame emitting devices
Use of suitable air-horn to arrest back-fire flame

Provision For Drainage—Carbureter provided with attachment to insure direct drainage of over-flow gasoline to ground without traps or similar hazards

ELECTRICAL EQUIPMENT

Wiring Materials.—High-tension wires provided with proper insulation
Low-tension wires provided with proper insulation
Low-tension wires of ample copper capacity and mechanical strength to carry current load

Wiring Connectors.—Splices made in workmanlike manner and suitably protected
Terminal connections used on all wires

Wiring Supports.—All wires supported at frequent points to avoid drooping, chafing and excess vibration

Wiring Protection.—From mechanical injury
Damage to insulation from heat
Exposed to accumulation of grease, oil or gasoline

Devices.—Instruments and devices of suitable design
Fuses or other automatic overload protective devices used in low-tension circuits

Circuits.—Provision for inspection lamp circuit
Ignition system not of multiple spark-plug type

EXHAUST SYSTEM

Position.—Exhaust pipe and muffler above road clearance
Exhaust-pipe clearance from fuel tank and combustible materials
Exhaust not exposed to accumulation of grease, oil or drippings

Muffler and Cut-Out.—No cut-out used; if used, not operable from driving compartment
Discharge of exhaust directed away from combustible material
Muffler and connections installed in workmanlike manner
Muffler sufficiently strong to withstand internal explosions and not heat beyond reasonable point

Exhaust Heater.—Exhaust heater properly installed, avoiding excessive temperature rise in surrounding materials

MISCELLANEOUS

Mud Pan Construction
Horizontal Side Plates
Vertical Side Plates

The testing of the individual units that are used in automobile construction is very essential in order that the hazards may be reduced to a minimum. In the outline mention is made of the strength of the muffler to resist internal explosions. This is determined by mounting the muffler on a standard test block and subjecting it to repeated explosions. When the test is completed an examination of the muffler is made to ascertain the extent of the damage and the distortions. The head and the longitudinal seams must be intact and the baffles and the inner shells must not have become distorted to such an extent as to allow the hot exhaust gases to come in contact with combustible materials. Similar tests are made on all units, such as the carbureters; vacuum tanks; ignition, starting and lighting systems; exhaust heaters and numerous accessory devices. To minimize the inherent fire hazard incident to the design and construction of automobiles, the Underwriters' Laboratories at the request of an automobile company will send an engineer to the plant to analyze the vehicle according to the specifications printed above. The hazards that may ultimately cause a fire as shown by long experience, extensive tests and careful research are noted and recommendations for changes in the design are made. Usually these recommendations, such as additional supports for the fuel line and the wiring system or changing the exhaust manifold casting to give a greater clearance between the exhaust pipe and the toe-board involve only a slight increase in the cost.

In addition to examining automobiles at factories the fire hazards of accessory equipment should be minimized as much as practicable. Among the accessory devices received by the Underwriters' Laboratories for testing are engine heaters, heaters that employ exposed sparks and use gasoline for fuel, electric carbureters, manifold heaters and the like. When a device is submitted for examination and test a plan of investigation is drawn up to consider the extreme conditions under which the device may present a serious fire hazard. Tests are then conducted and the manufacturer's attention is called to features of the device that may have a bearing not only upon fire hazard but also upon the accident, collision and theft hazards.

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

BUREAU OF PUBLIC ROADS HIGHWAY TESTS

HIGHWAY research and the closely related problems of automobile transportation are now attracting a lively interest among engineers. At the open session of the Society's Highways Committee, held during the Summer Meeting, a large number of our members discussed very profitably the program of highway research initiated by the Bureau of Public Roads and planned as a cooperative project in which our Society, the National Automobile Chamber of Commerce, the National Research Council, the Post Office Department and the Rubber Association of America were invited to assist. Since this meeting at Spring Lake, N. J., the tentative plans have been perfected and the preliminary arrangements have progressed so far that actual tests are now under way.

The tests are being conducted at the Arlington (Va.) Experimental Farm of the Department of Agriculture where a series of concrete test-slabs, varying in thickness from 4 to 10 in., have been laid on three different types of subgrade, the latter having been chosen to represent extreme and average conditions. A number of trucks of different capacities and tire equipment have been chosen for use in the work.

The tests will embrace an extensive series of runs over the test-slabs with the trucks under various conditions of load and speed and with obstructions arranged and proportioned so as to simulate, as nearly as possible, actual service conditions; these conditions will be determined by making preliminary runs over a road whose roughness may be considered as typical. During these preliminary runs, an accelerometer suitably mounted upon the truck will give indications from which typical maximum-impact conditions can be determined and later duplicated upon the test-slabs by arranging the obstructions so as to produce equivalent impact-forces. The effect of these forces upon the road will be determined by strain gages mounted at various locations in the slabs.

It is hoped that the results of these tests, which will probably require more than a year to complete, will be of value not only to the highway engineer but as well to the designer and manufacturer of automobiles, tire and wheel equipment, etc. Furthermore, the outcome of the tests should prove to be of considerable importance in supplying a rational basis for future highway legislation.

The Society is keeping in close touch with the tests through its Highways Committee, the Truck Division of the Standards Committee and its Research Department.

MOTION AND FORCES BETWEEN WHEEL AND ROAD

A discussion of the motion and forces obtaining between the wheel of an automobile and the road appeared on p. 171 of the August issue of THE JOURNAL. This material was in the nature of a preliminary analysis and introduction to a paper by Dr. B. J. Babbitt of the Bureau of Standards in which the problem is treated mathematically. As announced in that issue of THE JOURNAL, it was hoped that this paper would be ready for presentation this month, but owing to an unforeseen delay we find it impossible to print the paper at this time. It will, however, appear in the near future.

GEAR-GRINDING AND TOOTH-FORMS

IN the paper bearing this title that was presented by Glenn Muffly at the March meeting of the Detroit Section and printed in the June issue of THE JOURNAL, a number of errors crept in. Some of these were typographical and others were due to mistakes or lack of clearness in the copy [illegible] by the author. While these errors will all be corrected when the paper is printed in the TRANSACTIONS, they are listed below so that members who desire to do so can correct the paper in their copies of THE JOURNAL.

p. 545—In the third line from the end of the second paragraph of the abstract "gear cutting" should read "gear grinding"

p. 546—The triangle at the left should have the right angle adjacent to the side marked "cosine" instead of opposite to it

p. 547—In the third line above Fig. 6 "*l*" should be "1"
In the caption of Fig. 8 "hobbing" should be changed to "rack tooth"

p. 548—Two of the tooth profile at the left of Fig. 11 should appear as a series of flat spots and not a smooth curve
In the line above Fig. 12 "two" should be changed to "four"
In the caption of Fig. 12 the words "carrying the grinding wheel" in the second line should be omitted

p. 549—In the caption of Fig. 17 "depth" should be changed to "width"

p. 552—The pressure angle value of "18 deg. 37 min." which occurs in the last two paragraphs in the second column should be "16 deg. 44 min."

p. 553—In the sixth line from the top and in next to the last line in the first column the angle should be "16 deg. 44 min." and not "18 deg. 37 min." as printed
In Fig. 24 the term "pitch angle" that appears four times in the central gear and once in each of the three other gears should read "pressure angle"
The steel tapes connecting the two base-circle discs in Fig. 25 cannot be seen. In each of the five views these tapes can be shown by drawing two lines tangent to the two circles and crossing each other like the base circle tangents do in Figs. 5 and 6. These tapes act as crossed belts causing the two discs to rotate at equal periph-

(Concluded on p. 249)

Automobile Head-Lamp Regulation

By James J. Shanley[1]

Semi-Annual Meeting Paper

THE author outlines the present status of state regulation of automobile head-lamps and head-lamp devices as practised by the State of New Jersey. The 1922 Report of the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society was used as a basis, and the adoption of its recommendations was begun then.

The Commissioner of Motor Vehicles of New Jersey was instrumental, about 1921, in forming a Conference of Motor-Vehicle Administrators to hold quarterly meetings, its members including the administrators of 10 states who pledged themselves to secure the necessary legislation in their respective states to have these regulations put into effect. Later, out of about 200 devices considered, the committee recommended 22 that met the standard, and the conference adopted this list as constituting "approved" head-lamp devices in April, 1923.

NEW JERSEY was one of the pioneer States in the regulation of glare from automobile head-lamps but, previous to 1923, we in New Jersey were more concerned about the elimination of glare than we have been about the actual amount of driving light available to a driver.

When the Department of Motor Vehicles took up this problem some years ago, many of the devices on the market that were intended to eliminate glare were very crude. The department approved for use many of these devices on the theory that almost anything that diffused or broke-up the beam of light was preferable to the use of a naked reflector. However, when the 1922 Report of the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society became available to us, we changed our viewpoint and began to adopt measures to conform to its recommendations. Incidentally, the authority of Motor Vehicles Commissioner Dill under our present statute is such that no additional legislation was necessary.

Commissioner Dill was instrumental about 2 years ago in forming the Conference of Motor-Vehicle Administrators with the officials of the following States as members: Maine, Vermont, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland and Ohio. Commissioner Dill of New Jersey is president of this conference, which holds quarterly meetings; one of its objects is the securing of uniform automobile laws in the neighboring member States.

At the April, 1922, meeting of this conference, the head-lamp situation was taken up and, at the July, 1922, meeting, the conference adopted the 1922 specifications of the Illuminating Engineering Society as a standard for the approval of head-lamp devices. The members of the conference pledged themselves to secure the necessary legislation in their respective States to put these regulations into effect.

At this July, 1922, meeting, the conference also appointed a special head-lamp committee to examine head-lamp devices and to recommend to the conference which devices to approve and which to reject as not conforming to the 1922 Standard of the Illuminating Engineering Society. After much preliminary work, this special committee held two all-day sessions in February, 1923, at the Electrical Testing Laboratories, New York City, and two sessions at Hartford, Conn., in April, 1923. This committee drew up a composite list of all devices approved in any of the member States and then proceeded to consider every device that used the Illuminating Engineering Society's 1922 Specifications as a standard. Out of almost 200 devices considered, the committee found about 22 that, in its opinion, met the standard. The committee recommended these devices to the conference at its April, 1923, meeting at Hartford, and the conference adopted the committee list as approved devices.

The member States of the conference are now making this list official as quickly as the statutes of the various States will permit. Commissioner Dill, of New Jersey, has ordered these regulations into effect in New Jersey on July 1, 1923. He realizes that the mere use of approved devices will avail nothing unless these devices are installed properly. He is now working out a system of stations under department supervision where car-owners can have their head-lamps aimed and focused properly.

It has come to Commissioner Dill's notice recently that many head-lamp devices on well-known cars are installed improperly or carelessly when leaving the factory, and he respectfully asks the cooperation of automotive engineers who are engaged actively in car production in securing proper head-lamp installation, to the end that the menace of glaring lights be removed from our highways.

[1] Inspector, department of motor vehicles, State of New Jersey, Trenton, N. J.

GEAR-GRINDING AND TOOTH-FORMS

(*Concluded from p.* 248)

eral speeds in opposite directions. The point at which the tapes cross establishes the pitch diameter for each gear

p. 558—In the 22nd line from the bottom of the first column "a_2" should be changed to "e"; in the 19th line "b_2" should be changed to "f"; in the 18th line "b_1" should be changed to "c" and "a_1" should be changed to "b"; in the 16th line "a_1" should be changed to "b" and in the 15th line "b_1" should be changed to "c." In the 19th line from the bottom of the second column "Fig. 5" should be changed to "Fig. 3," and in the 16th line "the tangent tt" should have read "the tantangent tt_1"

SOCIETY MEETINGS

CLEVELANDERS VISIT TIRE FACTORY

Air-Cushion Tires Demonstrated and Their Effect on Car Performance Discussed

J. E. Hale

Journeys afar seem to be a specialty of the Cleveland Section. Akron, capital of rubberdom, was the destination of its latest pilgrimage on Aug. 17 when some 50 members enjoyed the hospitality of the Firestone Tire & Rubber Co. James E. Hale, exponent of doughnut tires, who acted as chief host, read a paper on the qualities of monster pneumatic tires, which are formally, but less generally, known as air-cushion tires. All the Firestone factory buildings were inspected during the visit. Golf in the morning and a dinner with cabaret trimmings in the evening were included in the day's diversified program.

Soon after arriving, the visitors assembled at the Portage Country Club, where they learned that an 18-hole handicap golf tournament had been arranged for their entertainment. Rivalry was intensified by the broadcasting of the news that an unblemished cord tire awaited the member whose net score or handicap enabled him to turn in the lowest net score. The prize went to G. W. Carlson whose generous handicap of 20 reduced his net score to 69. Dan Swander was a close second with 71, net. R. S. Leonard recorded the low gross score of 89, which is fair shooting among friends. One partly used tube of tire cement was presented to A. J. Scaife for the unusual feat of accumulating 150 strokes in a mere 18 holes and in a half-day's play!

After a palatable lunch at the Firestone Club, the visitors were loaded into cars of sundry and divers makes, all of which were equipped with air-cushion tires. The first stop was at the Firestone rim plant where clincher and straight-side rims were seen in process of manufacture. Flat strip-stock enters at the end of a one-story building and is rolled into circular form, the ends are butt-welded electrically, and the basic rim is then ready to start on its way past rolls, punches and inspectors. Cleaning and plating are done automatically by chain conveyors that carry the rims through cleansing solutions, plating tanks and dryers to the calloused hands of the car loader, who waits impatiently at the end of the last chute. Gravity and the circular shape of the rims solve all conveyor problems; the passage from operation to operation is just one roller-coaster after another. This is material handling reduced to its simplest form.

Wire-braiding machines, the bobbins of which chase one another about on a surface plate like skaters cutting graceful figure 8's on the ice, fascinated the members who saw them in the rim plant. Flat braided wire is used as the foundation for tire beads, the footage consumed daily reaching large figures.

Passing on to the tire plants, the visitors were shown the highly developed unit devoted to building 30 x 3½-in. clincher tires exclusively. Huge continuous calender machines, rolls that spat tread strips resembling the licorice sticks of our youthful days, the making of inner tubes, tire-building machines, tall steam-curing cylinders and interesting automatic machines and conveyors too numerous to mention were passed in rapid succession. Each step in the tire-building process was explained by men familiar with the details of every operation. Thorough inspection was also made of the expansive plant devoted to manufacturing tires of the larger sizes. Weary of limb, but possessing a complete picture of tire and rim manufacture, the members assembled in the Firestone auditorium.

Previous to the technical meeting, demonstrating cars transported the visitors over a route that traversed railroad and street-car tracks, the brick pavement being dotted with chuck-holes and other irregularities conducive to the riders' discomfort. The air-cushion tires rolled smoothly over these obstacles and convinced the passengers that a distinct improvement in ease of riding had been accomplished. Mr. Hale presented substantially the same technical paper that made such a favorable impression at the Semi-Annual Meeting. This paper was printed on p. 41 of THE JOURNAL for

Sections Secretaries

BUFFALO SECTION—J. W. White, 1700 Elmwood Avenue, Buffalo
CLEVELAND SECTION—L. L. Williams, 1051 Lake View Road, Cleveland
DAYTON SECTION—Ernest Dickey, Delco-Light Co., Dayton, Ohio
DETROIT SECTION—K. L. Herrmann, 416 Capitol Theater Building, Detroit
INDIANA SECTION—George T. Briggs, Wheeler-Schebler Carburetor Co., Indianapolis
METROPOLITAN SECTION—F. H. Dutcher, Columbia University, 117th Street and Broadway, New York City
MID-WEST SECTION—H. O. K. Meister, 111 West Washington Street, Chicago
MINNEAPOLIS SECTION—Phil N. Overman, 10 South 10th Street, Minneapolis
NEW ENGLAND SECTION—V. A. Nielsen, 701 Beacon Street, Boston
PENNSYLVANIA SECTION—A. Ludlow Clayden, Sun Oil Co., Philadelphia
WASHINGTON SECTION—C. H. Young, 724 Ninth Street, North West, City of Washington

July, the comments made in the discussion being reported briefly on p. 67 of the same issue and in full on p. 213 of this issue. The effects on car operation were treated fully and included such topics as car speed, steering ability, front-wheel shimmy, traction, braking control, punctures, blow-outs, and side-sway.

Leaving the aroma of smoldering rubber and the din of machinery, the pilgrims returned to the Portage Country Club where their ravenous appetites were appeased by a sumptuous "spread" set by the Firestone hosts. Such delicacies as steam-cured duck, gum-dipped olives, para biscuits and caucho balls in latex were announced on the menu, but the chef, being a non-member of the rubber ring, bounced dishes of greater appeal off the stove. Thence followed a chirping and colorful cabaret accompanied by vocal excesses on the part of the assembly. Preference ran to the following version of the banana anthem:

Yes, we have no balloon tires; we have no balloon tires today.
"Doughnuts" we don't make 'em.
Who is there would take 'em?
And too many balloons "blow" away.
We've low pressure Air Cushion Ti-ers!
All triers are buyers—
But Yes! we have no "balloon" tires; we call them "Air Cushion" today.

Fleet of Cars That Transported Akron Visitors on Low-Pressure Air

In closing these impressions of a successful meeting, it is fitting to record that a vote of thanks was extended to the officials of the Firestone Tire & Rubber Co. for their hospitality. Technical talk, educational factory-inspection, sports and entertainment were mixed in the proper proportions, so that all who attended the meeting felt fully repaid for the time taken from business duties.

NASH MOTORS WILL WELCOME MID-WEST

Cleveland is not the only Section to include a plant inspection in its year's program. On Sept. 21, the Mid-West Section will spend the day at the Nash plant in Kenosha, Wis. The morning will be devoted to golf, followed by an afternoon in the Nash plant and a dinner closed with informal speeches.

Prescott Ritchie is chairman of the Program Committee that has provided this get-together to begin the year.

CUTTING OPERATING COSTS IN TWO

John F. Duby Believes Proper Wheel Alignment Can Effect Big Savings

When John F. Duby of the John F. Duby Co. addresses the New England Section at its September meeting he will be prepared to show how the cost of operating a car can be reduced from 5 to 50 per cent by merely using the often-overlooked adjustment already on the tie-rod.

Mr. Duby has worked out a short, easy method of calculating the correct setting to insure good steering with the least possible tire-wear. He has made a very thorough study of wheel alignment and is ready to answer any question on it.

Correct alignment will be discussed in detail and the effects of axles, tie-rods, king pins, radius-rods, steering-arms, steering gears and spring-suspension will be taken up separately. Both front and rear wheels will come in for close study. Methods of testing rear wheels and axles for accuracy and the usual causes of their misalignment will be studied in detail. Front wheels will be treated as completely. Toe-in and camber are also to be thoroughly discussed.

The meeting will be held at the Hotel Buckminster, Boston, on Sept. 11, beginning promptly at 8 p. m. It is surely unnecessary to point out the value of the meeting to Society members in the New England Section's territory.

Committee-work in the New England Section is in charge of the following: Papers, I. D. Shaw; Membership, Harry Fosdick; Meetings and Entertainment, Linwood H. Young; and Publication, James A. Moyer.

RECREATION MEETING IN DETROIT

Section Opens Season with Social Meeting at Detroit Boat Club

Believing that good-fellowship is conducive to successful professional activity, the Detroit Section will open its year of meetings with a social gathering at the Detroit Boat Club on Monday, Sept. 10. Swimming and canoe races will start the program at 4:30 in the afternoon. A war canoe race will be contested between two crews each consisting of 20 members. Diving contests will enable the more sylphlike geniuses of motordom to display their dexterity from the high board.

Dinner will be served at 6:15 and dancing will follow until 11 o'clock. There will be no speeches, technics or mathematical debates; the occasion is simply an informal social gathering of members, their wives and sweethearts. Tickets are priced at $3 and should be purchased in advance at the Section office, 416 Capitol Theater Building, Detroit.

Detroit Section meetings will be well advertised this year by a Publicity Committee under the direction of W. B. Stout. Other Detroit Section committees and their chairmen are: Meetings, George L. McCain; Membership, Harry Knepper; and Entertainment and Reception, H. M. Rugg.

ADJUSTMENT CRUX OF LAMP PROBLEM

Unusual Demonstration to Be a Feature of Metropolitan Section Meeting

R. N. Falge, of the National Lamp Works of General Electric Co., has demonstrated that the proper adjustment of

C. B. Veal, Treasurer F. H. Dutcher, Secretary

Two of the Metropolitan Section Officers for the Coming Year

Schedule of Sections Meetings

SEPTEMBER

[illegible]—Detroit Section—Dinner, dance and water sports
11—New England Section—Wheel Alignment—John F. Duby
17—Cleveland Section—The Single-Eight and Its Merits—J. G. Vincent
20—Metropolitan Section—Headlights—R. N. Falge
21—Mid-West Section—Inspection of Nash plant, Kenosha, Wis.

[illegible] already in use will solve many of the motorist's lighting problems. Better road illumination, the prevention of objectionable glare and the securing of a better and wider [illegible] all depend on the adjustment that will provide the most effective distribution of light.

Mr. Falge is prepared to do more than describe the type of [illegible]-ary and list the requirements for uniform and satisfactory lamp-service to do away with the difficulties of [illegible]. He will bring a real car into the meeting-room for a practical demonstration of better head-lamps and their proper adjustment.

Members of the Metropolitan Section who missed Mr. Falge's talk at Spring Lake will be able to hear it with the addition of new material at the meeting on Sept. 20 at the Automobile Club of America, 254 West 54th Street, New York City. The meeting, which is scheduled for 8 o'clock, will be preceded by a dinner at 6:30 p. m.

Metropolitan Section committee-chairmen are: C. B. Veal, Meetings; J. W. Lord, Membership; and A. C. Bergmann, [illegible].

EIGHT-IN-LINE ENGINES

Subject of Paper by J. G. Vincent at Cleveland Section Meeting This Month

J. G. Vincent, past-president of the Society and head of the Packard engineering staff, will be the speaker at the [illegible] and Section Meeting, Sept. 17. Eight-in-line engines and four-wheel brakes will be the subject of Mr. Vincent's [illegible] Engineering information of unusual value will be presented and a lively discussion is anticipated because of the general interest in the topic of the paper. Cleveland Section meetings are held in the Cleveland Hotel starting at [illegible] and are preceded by an informal supper and social get-together. All members of the Society are welcome.

Cleveland Section Committees

Committees have taken on a new importance in Cleveland Section [illegible]. There are more of them and, with [illegible] they [illegible] draw a larger part of the membership into active service. The Program Committee, Russell Begg, Chairman, includes a House Sub-Committee; Membership Committee [illegible] under the general supervision of [illegible] Wagner, are divided between the main committee and the [illegible] and Golf Sub-Committees. Publicity is [illegible] by a committee of the Entertainment Committee of which K. B. Britton is chairman.

Another of the innovations introduced by the new administration is *The Cleveland Junior Journal*, a well-printed [illegible] that looks like a miniature edition of the Society JOURNAL. Its purpose is to keep its readers well-informed on Cleveland Section affairs. Past meetings are reported and coming meetings announced in a way to draw a maximum attendance. A schedule for the whole year's program is published and suggestions are not only sought but made easy by a coupon to be sent to the Secretary. The Junior Journal also offers very practical assistance in a supplementary Employment Service. Seven men have been placed so far through this medium.

Cleveland is solving the problem of reaching members outside of Cleveland by the activities of a special Out-of-Town Committee: T. V. Buckwalter for Canton, Walter H. Allen for Akron and Charles S. Dahlquist for Detroit and the outlying districts of Cleveland.

COMMITTEE CHAIRMEN IN BUFFALO

The officers of the Buffalo Section share their responsibilities with two committees, one on Papers and Entertainment, the other on Public Relations. The chairman of the first is H. T. Youngren; of the second, J. G. Willet.

There will be no meeting of the Buffalo Section in September.

DAYTON'S SPECIAL COMMITTEE

Besides the usual committees on Membership, Entertainment, and Program, the Dayton Section has a special committee to award the Wright Brothers Medal. The chairmen of the Dayton committees, in the order given, are R. V. Hutchinson, Luzern Custer, George E. A. Hallett and J. H. Hunt.

The Dayton Section will not hold a meeting in September.

WELCOME READY AT INDIANA MEETINGS

Members and guests of the Indiana Section will be made to feel at home at every meeting by a Reception Committee headed by B. F. Kelly. William Guy Wall is responsible for the Papers and Meetings Committee and Charles A. Trask is chairman of the Membership Committee.

The first meeting of the new season will be held in October.

WASHINGTON PREPARES YEAR'S PROGRAM

In the Washington Section, two committees work in co-operation with the Governing Committee which has already prepared a tentative program for the new Section year. W. S. James heads the Meetings Committee; Paul B. Lum is chairman of the Membership Committee.

Technical meetings will be resumed in October.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between July 10 and Aug. 9, 1923. The various grades of membership are indicted by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ATKINSON, ROBERT (M) metallurgical engineer, Halcomb Steel Co., *Detroit,* (mail) 8424 Hamilton Boulevard.

BACHMAN, GRAYDON A. (E S) student, University of Minnesota, *Minneapolis,* (mail) 1409 Sixth Street, Southeast.

BAER, WALTER, D. (J) secretary and treasurer, Iron City Spring Co., 2920 Smallman Street, *Pittsburgh.*

BERSIE, HUGH G. (M) engineer, Haskelite Mfg. Corporation, 133 West Washington Street, *Chicago.*

BOLGER, JOHN F. (A) vice-president and sales manager, Allbestos Co., Logan, Philadelphia, (mail) 419 West Upsal Street, *Mount Airy, Philadelphia.*

COLLIER, J. F. (M) manager service, Reo Motor Car Co., Lansing, Mich., (mail) 26 West Warren Avenue, *Detroit*

CUSHMAN, E. H. (A) automotive engineer and assistant manager, Myron D. Kidder, Inc., *Portland, Me.,* (mail) 343 Forest Avenue.

CUSTER, L. L. (M) president and treasurer, Custer Specialty Co., *Dayton, Ohio,* (mail) 119 Franklin Street.

DURHAM, CADY B. (M) assistant general manager, Buick Motor Co., *Flint, Mich.,* (mail) 301 East Hamilton Avenue.

FREEMAN, F. P. (A) superintendent of motor equipment, Kaufman's Department Stores, Inc., Fifth Avenue, Smithfield and Diamond Streets, *Pittsburgh.*

GARRARD, LESTER A. (J) research engineer, Standard Oil Co. of New York, New York City, (mail) care of Socony, *Manila, P. I.*

GRANER, ADOLF (M) president, Wisconsin Magneto Co., *Milwaukee,* (mail) 824 North Cambridge street.

HANNA, R. W. (J) tool designer, Yellow Sleeve Valve Engine Works, East Moline, Ill., (mail) 1939 Pershing Avenue, *Davenport, Iowa.*

HENDERSON, CHARLES E. (A) purchasing supplies, Air Mail Service, Maywood, Ill., (mail) P. O. Box 6044, Sunny Slope Station, *Kansas City, Mo.*

HILBERT, FAYE W. (A) motor-vehicle inspector, Sinclair Refining Co., *Buffalo,* (mail) 24 Huntington Avenue.

HULING, JOSEPH B. (A) service-station foreman, International Harvester Co., Lagonda Avenue, *Springfield, Ohio.*

KELLER, A. (M) vice-president and works manager, Golde-Patent Mfg. Co., New York City (mail) 30 Gould Avenue, *Long Island City, N. Y.*

KENT, FRANK J. (A) patent lawyer, Cox, Kent & Campbell, 233 Broadway, *New York City.*

KERR, STEPHEN LESTER (E S) student, University of Utah, *Salt Lake City, Utah,* (mail) 153 South 13th East Street.

KINSEY, KENNETH HARRY (J) student, Purdue University, Lafayette, Ind., (mail) *Mentone, Ind.*

LANE, F. J. (A) salesman, Allyne-Zerk Co., Cleveland, (mail) 2681 Lawrence Avenue, *Detroit.*

LEWIS, JOSEPH CARLETON (A) service manager, Noyes Buick Co., 857 Commonwealth Avenue, *Boston.*

MACMILLEN, ROBERT D. (A) director of sales and service, Albert Frank & Co., 14 Stone Street, *New York City.*

MARTY, MATHEW J. (M) engineer, Chicago Mfg. Co., *Chicago,* (mail) 4308 North Monticello Avenue.

MATHEWSON, M. I. (M) experimental and designing engineer, Detroit Gear & Machine Co., *Detroit,* (mail) 670 East Woodbridge Street.

MAXIM, ALBERT (M) engineering mechanic, Ward Motor Vehicle Co., Mount Vernon, N. Y., (mail) 706 Trinity Avenue, *New York City.*

MAYES, W. A. (M) chief engineer, Martin-Parry Corporation, *York, Pa.*

MEAD, RICHARD O. (A) sales manager, American Wood Rim Co., *Owosso, Mich.*

PATTERSON, C. E. (M) works manager in charge of production engineering, Athey Truss Wheel Co., 5631 West 65th Street, *Chicago.*

PATTERSON, C. W. (A) lubricating engineer, Standard Oil Co. of Louisianna, *Memphis, Tenn.*

RANDOLPH, DONALD W. (J) assistant mechanical engineer, Bureau of Standards, *City of Washington,* (mail) 1741 P Street, Northwest.

ROBB, WILLIAM C. (A) assistant manager, Ohio Rubber & Textile Co., 158 Larned Street, West, *Detroit.*

SCHLINGER, W. J. (A) vice-president and general manager, Flint Varnish & Color Works, *Flint, Mich.*

SHEPARD, R. L. (A) metallurgist, Shepard Art Metal Co., *Detroit,* (mail) 141 Montana Avenue, West.

SHIMIZU, YUTARO (A) New York representative, Yanese Automobile Co., Tokyo, Japan, (mail) care of engineering department, Mitsui & Co., 65 Broadway, *New York City.*

SMELLIE, DONALD G. (M) 926 Gilmore Avenue, Northwest, *Canton, Ohio.*

STYRI, HAAKON (M) chief of research laboratory, S. K. F. Industries, Inc., *Philadelphia.*

SULLIVAN, ALAN P. (A) chief engineer, Stackpole Carbon Co., *St. Marys, Pa.*

TEACHOUT, J. HOWARD (M) production manager, White Motor Co., 842 East 79th Street, *Cleveland.*

THOMPSON, SYLVESTER T. (A) secretary and general manager, Duplex Engine Governor Co., Inc., Brooklyn, N. Y., (mail) 3 West 192nd Street, *New York City.*

WALLER, EINAR (M) designing engineer, General Motors Corporation, *Detroit,* (mail) 1704 Meldrum Avenue.

WEADICK, ROBERT M. (J) student, Franklin Institute, Boston, (mail) 366 West Fourth Street, *South Boston.*

WINDLE, E. HOWELL, (E S) student, Ohio State University, *Columbus Ohio,* (mail) 239 Oakland Park Avenue.

ZELKOSKY, J. THEODORE, JR. (E S) student, Stevens Institute of Technology, Hoboken, N. J., (mail) 305 Sixth Street, *West New York, N. J.*

Applicants *for* Membership

The membership committee requests that members send to the Society information regarding the applicants listed below. Communications should be addressed to the Secretary and should state clearly the facts which the Council should have for considering each application. It is requested that such communications be sent promptly.

[illegible], owner, Blackburn Oil Co., [illegible], S. C.

[illegible], Chief Engineer, Wellman Wagon Co., [illegible], Mass.

[illegible], Vice-President, Vanadium Co., Detroit.

[illegible], Purchasing Agent, Rock Island Arsenal, Rock Island, Ill.

[illegible], assistant sales manager, Steel Products Co., Chicago.

[illegible], Detroit.

[illegible], Iowa State College, Ames, Ia.

[illegible], Chief Engineer, Automatic Gas & Stove Co., Wichita Falls, Tex.

[illegible], Detroit.

BEMAN, A. E., general manager, C. G. Spring Co. of Ohio, *Cleveland.*

BENSON, RAY M., assistant chief of division, Department of Commerce, *City of Washington.*

BENSSON, ANDR. J., designer, International Motor Co., *New York City.*

BOGOSIAN, A. A., research engineer, Chalmers plant, Maxwell Motor Corporation, *Detroit.*

BRAD, [illegible], H., automotive engineer, Rock Island Arsenal, *Rock Island, Ill.*

BRANT, ARTHUR F., manager of drafting room, Studebaker Corporation of America, Fayette Avenue, *Detroit.*

BRIGGS, REX E., aeronautical engineer, Glenn L. Martin Co., 16,800 St. Clair Avenue, *Cleveland.*

BROWN, KRAEMER, engineer on technical staff, American Bureau of Shipping, *New York City.*

BUCK, THOMAS B. N., Shellenburg & Co., *Philadelphia.*

BUSH, FRANK L., assistant sales manager and experimental engineer, Hayes Wheel Co., *Jackson, Mich.*

MALIN, EDWARD A., general inspector, Gulf Refining Co., *Pittsburgh.*

McMILLEN, JOHN F., mechanical superintendent, Yellow Taxi Corporation, *New York City.*

MEYER, WALTER, manufacturing engineer, Maryland Refining Co., *Pierce City, Okla.*

MITCHELL, F. A., vice-president, Bristow Co., *Port Townsend, Wash.*

MORGAN, [illegible] B., *Wombleville, Pa.*

NEUMAN, H., draftsman, F. D. H. Co., *Cuyahoga Falls, Ohio.*

O'BRIEN, JOSEPH F., president, Joseph F. O'Brien Mfg. Co., *New York City.*

RAMSEY, W. CLARENCE, instructor, El Paso Public Schools, P. O. Box 1408, *El Paso, Tex.*

REMSEN, LOUIS, assistant to superintendent, General Electric Co., *Schenectady, N. Y.*

RILEY, JOHN, chief designer, Automatic Gas Producers, Ltd., *Birmingham, England.*

ROBINSON, RICHARD H., student, Tri-State College, *Angola, Ind.*

SCHUETTE, A. F., chief inspector, Falls Motors Corporation, *Sheboygan Falls, Wis.*

STEPHENS, E. A., branch manager, Westinghouse Air Spring Co., *Long Island City, N. Y.*

STOUT, WILLIAM ROBERT, metallurgical engineer, Bethlehem Steel Co., *Bethlehem, Pa.*

WILLIAMS, STEEL, Co., 606 South Michigan Avenue, *Chicago.*

ZIMMERMAN, J. T., Jr., merchant, 167 South Street, *West New York, N. J.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIII October, 1923 No. 4

Chronicle and Comment

The Production Meeting

LAST fall the Society held a Production Meeting at Detroit, the first of its kind held by the Society and probably the best attended professional meeting of the Society. The second Production Meeting will be held at Cleveland this month, and this meeting is drawn to your attention to show that the question of production on a quality basis is having the attention of engineers. (See page 347 this issue.) Efforts are being made to draw the production and the engineering departments into the close harmony and cooperation that is desirable if we are to serve the public honestly and to the best of our ability.—C. S. Dahlquist.

National Aeronautic Convention

AERONAUTICAL engineering progress in this Country has been rapid during the past year. Many speed, altitude and duration records of importance are now held by American airplane pilots. We have seen the wide expanse of our Continent traversed without stop. The Air Mail, in addition to maintaining its past record of superior performance, has proved its ability to fly the mail from Coast to Coast in a little more than a day. Night flying has been undertaken and proved practical. American engineers and artisans have constructed the ZR-1 and demonstrated her fitness as an air-carrier. These accomplishments are sufficient reason for pardonable pride in the proficiency of our aeronautical engineers, the more so because of the apathy displayed by the general public and the large majority of our business men.

As a fitting conclusion to this year of aviation progress, the Third National Convention of the National Aeronautic Association and International Air Races are being held in St. Louis Oct. 1-3. May these two important events stimulate a greater and more sincere interest in commercial air-transport, the all-important backbone of a prosperous aeronautical industry.

The Motorbus

THE cooperation between the American Electric Railway Association and the Society of Automotive Engineers, inaugurated by the address of President Emmons of the former organization at the Automotive Transportation meeting of the Society in Cleveland last April, will be continued at the A. E. R. A. Convention at Atlantic City this month. In the afternoon of Tuesday, Oct. 9, President Alden, of the Society, will present a discussion of a report on the subject of Bus Operation, prepared by the Transportation and Traffic Association, an affiliated section of the American Electric Railway Association. It is expected that other members of the Society will take part in the discussion of this very interesting and important subject. The traction lines are naturally giving greater and greater attention to the possibilities and proper economic status of the motorbus, which undoubtedly is a medium of transportation that will henceforth be much more widely availed of.

Martyrs to Science

DURING the afternoon of Sept. 20 an explosion of great violence occurred in the engine testing laboratory in the Bureau of Standards, City of Washington. One man was killed instantly, three others were injured so seriously that they died during the night, and four others were seriously burned or cut.

The explosion occurred in the north altitude chamber in which there was being conducted an acceleration test at low temperature of an automobile engine using aviation gasoline. The work in progress was part of a cooperative fuel investigation undertaken jointly by the Society, the American Petroleum Institute and the National Automobile Chamber of Commerce. It is stated officially and there appears to be no doubt that the explosion was due to the ignition of an explosive mixture in the chamber. No one was in the chamber at the time of the explosion, but flame issuing from it burned directly those in its path outside the chamber and ignited inflammable material including the fuel-measuring apparatus used in the test.

The dead are: Stephen M. Lee, a junior member of the Society who was in charge of the test in progress; James E. Kendig, assistant electrical engineer of the Bureau who was assisting in the test work; Urban J. Cook, machinist, and Dr. Logan L. Lauer, who was not engaged in any way in the work. Those seriously injured are Roger Birdsell, research associate engaged in the investigation, H. K. Cummings, C. W. Elliot and F. E. Richardson. The heroism of members of the Bureau

staff in rescuing the injured from the furiously burning wreckage minimized the loss of life.

[illegible] suffering from this most deplorable disaster, the members of the families of those killed and injured, the officers of the Bureau and all those connected with the [illegible] investigation, have the deepest sympathy of all of the members. As has been aptly said by Secretary of Commerce Hoover, the men were martyrs to the experimental work through which science finds its [illegible] toward nobler usefulness.

Our Japanese Members

NO peacetime world calamity has stirred the sympathies of our Nation more deeply than the recent earthquake in Japan. Concrete expression of this feeling is going forward to the Japanese through the ever faithful services of the Red Cross. However, it seems fitting to record here an expression of concern to the members of the Society who were directly affected because of their residence in the quake and fire-swept areas. Our records show that fifteen of these resided in Tokyo. It is hoped that all were fortunate enough to survive this deplorable disaster so that their engineering knowledge and experience may be available for the labors of reconstruction.

Practical Brake Testing

ORDINANCES requiring that automobile brakes be maintained at a certain standard degree of efficiency exist in many of the larger cities, but their enforcement has been impractical for many reasons. Most important of these has been the lack of a simple and accurate method of conducting brake tests. The staff of the Bureau of Standards is offering a solution to this problem in the form of a registering decelerometer by means of which brake performance can be readily determined.

In conducting a brake test, the decelerometer is merely placed upon the floor of the car under observation. The driver is requested to attain a selected speed, apply the brakes with his full strength and keep them applied until a dead stop is effected. During the period of braking the decelerometer registers the rate of deceleration in feet per second per second on a suitable dial. The observer can see readily whether the rate of deceleration has always exceeded a minimum considered to represent acceptable braking performance.

This Bureau of Standards method has many advantages. The tests can be made by untrained observers; the readings are accurate and not subject to correction for [illegible] variables; the instrument itself is portable and self-contained and requires no connection with the vehicle, engine or wheels. Tests can be made in a very short time since no measurements of distances need be taken. It is not improbable that this method of brake testing will come into universal use, particularly if the police or other agencies attempt to enforce brake-inspection ordinances.

1922 Transactions

COPIES of Part I of THE TRANSACTIONS for 1922 [illegible] offered to those of the members who [illegible] them. In accordance with the resolution of the Council copies of THE TRANSACTIONS for the last half of 1922 will be sent without charge to members who paid dues for the first half of the fiscal year beginning Oct. 1, 1922, provided a written request is received within 60 days after a notice to order has been published. Copies of [illegible] THE TRANSACTIONS cannot be guaranteed to members who do not place their orders by Nov. 5. Members who have not sent in the order blank for Part II of THE TRANSACTIONS for 1922 should do so at once. The blank will be found printed in the advertising section of the September JOURNAL, p. 83.

Proper Dimensioning

THE report submitted by Earle Buckingham on Tolerances, which appears in Tentative Standardization Work in this issue of THE JOURNAL, is of exceptional value. Those who do not agree with his statement that non-mating surfaces should have bilateral or unilateral tolerances, depending on the nature of the variations which develop in manufacture, and that, with few exceptions, mating surfaces should have unilateral tolerances, should submit their views to the Society for consideration. The entire matter is too far-reaching to expect that acceptable decisions thereon can be made without the active cooperation of the industry at large.

A. E. A. Convention

AT the seventh annual summer meeting of the Automotive Electric Association at Eaglesmere Park, Pa., Sept. 11 to 14, at which joint sessions were also held with members of the Automotive Electric Service Association, a number of subjects of importance to the electrical automotive apparatus manufacturers and servicing organizations were discussed. The Standardization Committee's report on the adoption of four standard sizes of starting motors, to be referred to as Nos. 1, 2, 3 and 4, was approved by the Board of Governors. It was believed that this range of sizes, or capacities, will be adequate for at least a large proportion of automobiles electrically equipped. It was intimated that the Battery Division of the committee might consider standardizing a range of capacities for batteries to be used with the standardized sizes of starting motors and generators, the A. E. A. having previously adopted four sizes of generator. The committee also reported progress toward developing a standard method of making torque tests on starting motors and discussed the desirability of having a standard electrical test for ignition apparatus.

Several members of the committee whose investigation as to why the S. A. E. Standards for generator and starting motor mountings are not used more extensively, especially by the larger car manufacturers, explained that it is usually because of reasons important enough to the individual manufacturers; that probably most of the smaller manufacturers do use the standards, and that it would not be reasonable to expect this situation to be materially changed. It was felt that the present S. A. E. Standards might be improved somewhat, in certain details, and by adding a small generator mounting, but that no action should be taken toward changing them radically. Several members of the A. E. A. Committee are also members of the Electrical Equipment Division of the S. A. E. Standards Committee, and close cooperation between the two bodies is had in this work.

In the session at which electrical servicing was discussed, it was indicated that in general the servicing of electrical equipment on automobiles should be done by authorized electrical service-stations rather than by the local car-dealers or the electrical apparatus manufacturers. This naturally led to discussion of the basis for service charges to the customer, but no one system was favored, it appearing that the "flat-rate" system has worked out well in some localities, while the "predetermined charge" has proved satisfactory in others.

The Packard Single-Eight

By J. G. Vincent,[1] *assisted by* W. R. Griswold[2]

Cleveland Section Paper *Illustrated with* Photographs and Drawings

STATING the fundamental characteristics of the modern motor car under the headings of performance, safety, economy, comfort and taste, the authors define these terms and discuss each basic group. The specifications of the car in which the single-eight engine is installed are given, and the reasons governing the decision to use an eight-cylinder-in-line engine are enumerated.

Following a somewhat lengthy discussion of the components of engine performance, the design of the engine is given detailed consideration under its divisions of crankshaft design and the methods employed, gas distribution, the operation of the fuelizer, cylinders, valve gear and the arrangement of the accessories. Transmission design and the wearing quality of gears receive similar treatment.

Brakes and steering are subjects that are treated at some length, arguments being presented in favor of four-wheel brakes and reasons given for their adoption, together with a discussion of their effect on steering ability and of the mechanics of brake construction. Comfortable steering, axle construction, steering-gear efficiency and axle noise, are other subjects that are considered in detail. The paper is illustrated profusely and pertinent tabular data are included.

The mathematical analyses are made in appendices that will appear in the November, 1923, issue of The Journal.

UNDER the stimulus of the reaction from the great social upheaval that receded into the peace of 1918, engineers of the automotive industry began at once to adapt their product, and even the industry, to the new set of conditions prevailing. The period that followed saw many new expressions in the subsequent diversified designs, but, in all, the natural and obvious endeavor of each engineer was to interpret the new conditions and to utilize the lessons of past experience and the results of technical analysis to the best of his ability for the improvement over his previous efforts. Such is the natural order of progress. Our latest expression is in the form of the single-eight.

In the endeavor to arrive at engineering specifications for the single-eight, we tried to classify the fundamental cardinal properties of the modern motor car. These characteristics we have enumerated as being (*a*) performance, (*b*) safety, (*c*) economy, (*d*) comfort and (*e*) taste. These are not necessarily arranged in their order of importance, as that relation depends on many factors and the relative and absolute values of each determine the characteristics of the whole. I shall, however, discuss each one of these basic groups briefly and attempt to show what each comprises.

Fundamental Characteristics

Performance may be regarded in the restricted sense; acceleration, speed and flexibility. This is largely an element depending on the relation of the engine power to the weight of the car and the responsiveness of the engine to the throttle.

Safety refers to the inbuilt safety, strength of parts to withstand the various kinds of stress, the arrangement and functioning of the mechanical features that are instruments for control, such as the functioning of the steering-gear and the brakes.

Economy is relative, but it always connotates the minimum expenditure of either time or money for a given class of transportation. Hence, I include under this heading dependability, life, accessibility and simplicity as well as gasoline and oil economy.

Comfort denotes physical comfort, either on the part of the driver or the other passengers. This implies certain chassis and body proportions and arrangements.

Taste I define as being the personal sense for the fitness of things. It relates to appearance, finish, upholstery, quietness, smoothness and, generally, all those things that make their appeal through our sense of beauty and harmony.

The characteristics of performance, safety and economy have more or less definite standards for comparison, but the elements of comfort and taste are judged largely by personal impressions. Hence, it is more difficult to define these elements except in an arbitrary manner.

Car Specifications

We gave careful consideration to each of these elements and finally arrived at the following specifications as representing our conception of the new car:

Wheelbase.—The wheelbase is to be contingent upon the space requirements for the engine when the body space from the back of the dash to the center-line of the rear axle is fixed at 88 9/16 in. for the five-passenger car and 95 9/16 in. for the seven-passenger car

Weight.—To be about 4200 lb. for the seven-passenger touring car, fully equipped and ready for the road

Tires.—The size to be 33 x 5 in. for both front and rear wheels

Acceleration.—To be from 5 to 50 m.p.h. in 18 sec. under ideal road conditions for the seven-passenger touring car with two passengers.

Maximum Speed.—To be 70 m.p.h. under ideal road conditions

Brakes.—The car to be equipped with four-wheel brakes

Engine.—To be of unit construction with clutch and transmission; inherently balanced for inertia forces and rotating couples; free from discernible forced vibrations and sensible critical speeds; simple and accessible

After deciding on these basic requirements, the next step was the selection of the type of engine.

Reasons for the Single-Eight Engine

Before presenting the reasons underlying the design of the single-eight engine, it must be understood clearly that one of the milestones marking the advance in en-

[1] M.S.A.E.—Vice-president of engineering, Packard Motor Car Co., Detroit.

[2] M.S.A.E.—Engineer in charge of analysis of design, Packard Motor Car Co., Detroit.

[illegible] progressive reduction of [illegible] vibratory motion, is [illegible] the rapid changes or fluctuations in the magnitude or the direction of forces, these fluctuations causing motion of the particles, the component parts or even the entire engine with its foundation. These changes in the magnitude or the direction of forces may be attributable to a change in the gas pressure or the inertia or may arise by virtue of the motion of the reciprocating and the rotating parts.

Specifically, engine vibration may be caused by an unbalance of the inertia and centrifugal forces, by the torque reaction and by the elastic distortion of the crankshaft and its supporting parts. The characteristics of these three causes are widely different.

Unbalance of the inertia and centrifugal forces is entirely of primary condition and depends upon the number and arrangement of the cylinders and the arrangement of the throws or cranks of the crankshaft. This unbalance produces forces that are comparatively small at low speeds but that increase very rapidly with an increase of speed. At high speeds, the inertia forces are very often greater than the gas pressure on the piston. The effect of unbalance is to move the entire engine with its supports, the movement at any instant being rectilinear or rotative, the latter being caused by inertia or centrifugal couples.

The effect of the torque reaction or, rather, the fluctuation of the torque reaction, is a function of the steadiness factor or steadiness of the turning moment of the engine, which is dependent upon the frequency of the impulses and the flywheel effect of the moving parts. At slow speeds, particularly, the fluctuations are greatest; but, as the speed of the engine increases, the steadiness factor becomes increasingly higher and, at very high speeds, the fluctuations are so small as to produce practically no vibration.

Vibration due to the elastic change of shape of the bodies making up the engine is the result of using parts that do not possess enough stiffness or that are not adequately supported to make a rigid construction. Vibration of this type usually occurs in periods; that is, there are certain speeds of operation in which the impressed forces are timed with the deflection and the recoil of the parts. Such vibration is not inherent to any particular cylinder arrangement and generally can be avoided by careful design.

Of the three kinds of vibration, the unbalance that is inherent causes the greatest disturbance and is to be avoided particularly. For this reason, we specified that the only engine designs we would consider were those that are balanced inherently.

Outstanding Features of Engine Performance

We [illegible] of engine performance in the broadest sense, including not only power and activity but also economy and smoothness. An outline to show the components and [illegible] appears as follows:

POWER

(1) [illegible]
(2) [illegible] of cylinders, valving and manifolding

ECONOMY

(1) [illegible]
(2) [illegible] Arrangement of [illegible] design of parts and [illegible]
(3) [illegible] Arrangement of cylinders, firing [illegible] and use of a fuelizer
(4) *Quality.*—Design of details, accuracy of manufacture, adaptation and quality of material, safety factors, area of wearing surfaces, lubrication and protection from foreign matter

SMOOTHNESS

(1) *Balance.*—Crankshaft and number and arrangement of cylinders
(2) *Torque Reaction.*—Number and arrangement of cylinders
(3) *Elastic Distortion.*—Number of cylinders, length of shaft, diameter of shaft, number of main bearings, crankcase rigidity, engine mounting and use of a vibration damper

We see that the cylinder arrangement enters into almost every consideration. The relative value of the cylinder arrangement, as well as the final layout of the engine, depends first upon the power requirement, because this affects the total piston displacement. Several cylinder arrangements are available to approximate the desired results, but perhaps only one is best adapted to a given size of engine. I wish to make myself clear on this point by qualifying what I mean by the best arrangement. The remainder of the chassis must, of course, be considered in order that the coordination shall give beauty of appearance and also the proper riding balance to the finished car. The best cylinder arrangement is altogether dependent on the relative values that the designer arbitrarily assigns to the major elements of power, economy and smoothness, while still another element, the cost of manufacture, would be given considerable importance for many classes of car.

Preliminary calculations showed that a total displacement of about 360 cu. in. was necessary to meet the power requirements. This, reduced to dimensions for different numbers of cylinders, gives approximately those stated in Table 1.

TABLE 1—APPROXIMATE BORE AND STROKE

Number of Cylinders	Bore, In.	Stroke, In.
6	3¾	5½
8	3⅜	5
12	3	4¼

Since an uncompromising stand toward the requirement of inherent balance was taken, it first appeared that the choice would be either the 6 or the 12-cylinder engine, the latter obviously embracing the V-type construction. On analyzing the six-cylinder design, we considered that the large size of the individual cylinder was a fundamental disadvantage, involving as it does relatively poorer efficiency, heavier reciprocating parts and heavier individual impulses, all of which are important when the speed range is to reach from 3000 to 3200 r.p.m.

In six-cylinder construction, the mass inertia of the entire engine about the point of oscillation, generally near the center of the crankshaft, does not increase at a proportional rate to the individual impulses with increasing cylinder dimensions and, therefore, the fluctuation of the torque reaction, particularly at low speeds and full power, is considerably more than with smaller cylinders. This detracts somewhat from the smooth running of large six-cylinder engines, a result that we were striving to attain. In other respects, the six-cylinder design had admirable characteristics.

Similar scrutiny of the 12-cylinder design led to somewhat different conclusions. The 12-cylinder engine is inherently balanced in inertia forces and rotating couples; and the great overlap of the power impulses

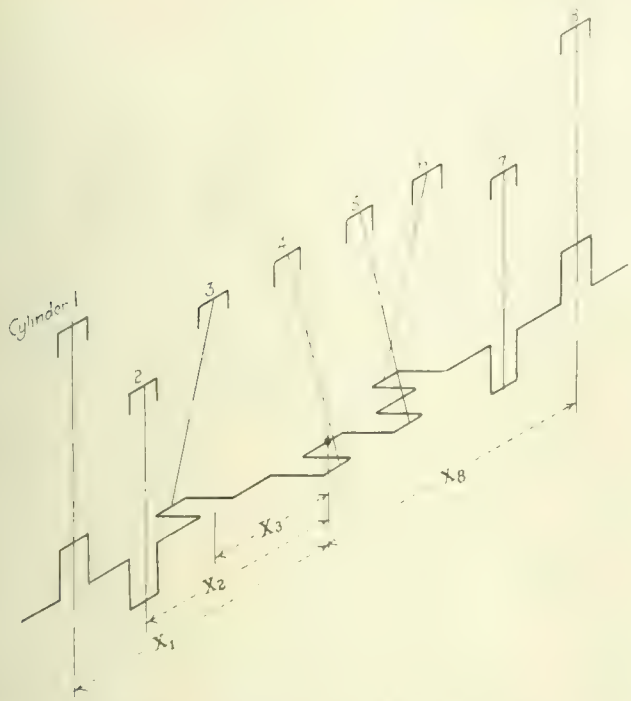


FIG. 1—GENERAL ARRANGEMENT OF THE PISTONS AND CRANKSHAFT THROWS IN THE STRAIGHT EIGHT-CYLINDER ENGINE

produces an almost constant torque, the fluctuations of the torque reaction being practically zero. The cylinder size, while comparatively small, could not be considered as a fundamental objection, yet it was felt that, after considering the average operating conditions, the fullest advantage could not be taken of such a small cylinder. The greater complication and inaccessibility of the V-type construction appeared to be the chief disadvantage. Without unduly spreading the cylinder centers, it is impossible to employ a main bearing adjacent to each crankpin, a construction that possesses great merit in the elimination of elastic distortion under the influence of the dynamic forces. This practically limits the crankshaft design to the three-bearing type, in which case the necessary rigidity can be obtained by employing a shaft of relatively large diameter for the size of the cylinder. The inaccessibility of the valves being an objection that we wished to eliminate, together with a desire for a more simple construction, led to an examination of the eight-cylinder-in-line type of engine.

An analysis of existing automobile engines of the eight-cylinder-in-line type, which were really nothing more than two four-cylinder engines with the crankshafts

[This will be published in the November, 1923, issue of THE JOURNAL.]

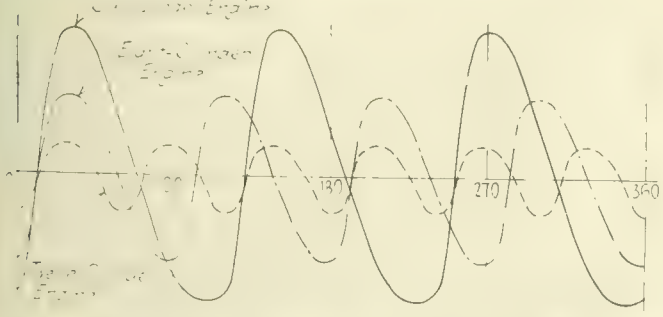


FIG. 2—TORQUE-EFFORT CURVES FOR 6, 8 AND 12-CYLINDER ENGINES OF EQUAL TOTAL PISTON DISPLACEMENT

90 deg. apart and constructed in a tandem arrangement, showed that while the inertia forces balanced so far as plane motion is concerned, a rather large couple due to the secondary inertia forces of each four-cylinder engine existed. This design was at once rejected because it did not meet the original specifications. Therefore, an examination for balance was made of other possible arrangements. It was found that the crankshaft, in which the middle four throws were arranged in a plane of 90 deg. from the outer four throws, gave a condition to the engine of practically perfect balance of plane forces and inertia couples. This crankshaft arrangement is shown in Fig. 1. Appendix 1 gives a rigorous mathematical analysis of the general case of engine balance with a special treatment for eight-cylinder-in-line engines.[3]

We consider the cylinder size to be well balanced, as our experience indicates that these dimensions occupied a rather medium position between small and large cylinders and is well adapted to the average conditions of operation, yet taking full advantage of the economical factors, such as the compression-ratio. It might appear that the fluctuation of the torque reaction was compromised, but this is not essentially true, for the frequency, as well as the magnitude of the impulse fluctuations, is an element affecting the amplitude of the vibration produced.

Fig. 2 shows the torque diagram for the three different engines; the 6, the 8 and the 12-cylinder designs that were considered for the new car. These engines are

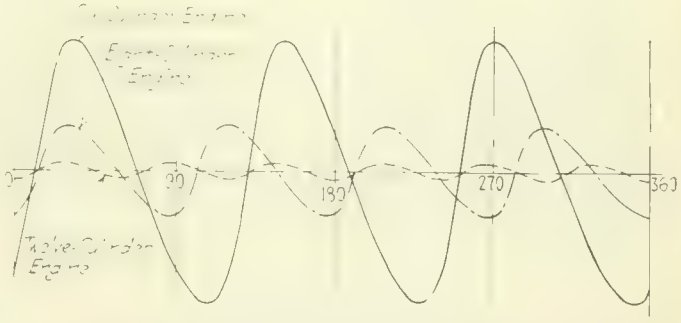


FIG. 3—RELATIVE AMPLITUDE OF VIBRATION DUE TO FLUCTUATIONS OF TORQUE REACTIONS FOR 6, 8 AND 12-CYLINDER ENGINES OF EQUAL TOTAL PISTON DISPLACEMENT

approximately of the same total piston displacement and, for comparison, the same indicator-card and the same weight of the reciprocating parts per square inch of piston-head area are used for each. This puts each engine on a comparative basis, although it should be pointed out that the six-cylinder design is favored slightly by these assumptions. The torque variations appear in the ratio of 4.0 to 2.4 to 1.0 for the 6, the 8 and the 12-cylinder designs.

The amplitude of the forced vibration varies directly as the torque variation and the square of the time during which the torque acts, and inversely as the moment of inertia of the engine and its support. The moment of inertia should be about the same for each engine. Fig. 3 is a series of curves showing the relative amplitude of these vibrations, which are in the ratio of 16.0 to 5.5 to 1.0 for the 6, the 8 and the 12-cylinder designs respectively. Thus, the amplitude for the 6-cylinder design is 16 times that for the 12-cylinder design. The fact that the 8-cylinder amplitude is 5.5 times that of the 12-cylinder design is not necessarily significant; for, while the vibration from the torque reaction from the

six-cylinder is hardly discernible in operation, the difference in the magnitude and the damping influences are sufficient to modify the vibration of the eight cylinders. This shows that no practical advantage in this respect is obtained with 12 cylinders.

The eight-cylinder design possesses the characteristics of simplicity and accessibility almost to the same degree as that of the six-cylinder, and the straight-line construction permits the use of a main crankshaft bearing adjacent to each crankpin. The length of engine was found to be very little more than that of the equivalent six-cylinder engine and provided a general chassis layout that possesses all the qualities of appearance that were desired.

To be absolutely sure of our ground and to determine whether any fallacies existed in our logic, we designed and built several cars having each type of engine. The engines were designed according to our most uptodate engineering knowledge and were built in our own shops.

Fig. 1—Indicator Analysis of Torsional Vibrations at Various Crankshaft Speeds of a Six-Cylinder Automotive Engine

Fundamentals were studied first; practical results were compared with the results of the theoretical analysis and, where both practice and theory agreed, that proved the fundamental weaknesses or advantages of each type. Each engine had to stand or fall on its own merits and, at the end of nearly 3 years of development work, the single-eight engine surpassed the other two so far that it became the unanimous choice of our entire organization.

Crankshaft Design

The proportioning of the crankshaft was carried out with two principal thoughts in mind, vibration and the life of the bearings. Engine vibration, as stated, depends on balance, torque reaction and elastic distortion. Balance and torque reaction having already been discussed, they can be dismissed from further consideration, and elastic distortion is the remaining element.

Vibration due to elastic distortion is most pronounced and generally only discernible when a condition of resonance occurs. The action can be described as composed of two separate parts. The impressed force due to an explosion causes, we will say, the shaft to bend out of its free position and, after the bending has proceeded to a certain point, the elastic force of the shaft overcomes the impressed force and causes the shaft to spring back or recoil in the same manner as a spring. If considerable friction happens to be present and acts as a damping influence, the shaft will resume its original shape; but if the damping influence is small, the shaft will spring beyond the free position until recoil takes place in the opposite direction. The shaft will thus vibrate to and fro like the prongs of a tuning fork. Should the impressed force be timed with the vibration, this is called resonance, the vibration will become stronger and stronger until the damping influence prevents any further growth.

Some damping influence is always present, either in the form of mechanical friction or friction of the particles of the material; therefore, the amplitude never becomes infinite although, in aggravated cases, the stresses in the parts may exceed the physical strength of the material. In less aggravated cases, failures may take place due to the fatigue of the material. All materials of construction are elastic, and steels, particularly hard steels, are among the most elastic. There is, therefore, some deformation of the parts due to the forces set-up by the explosions, or those arising from the motion of the various masses. The problem is to prevent sustained vibration, or resonance, and to reduce the forced vibrations to a point where they do not react on the senses.

Methods Employed

Two methods of accomplishing this are available, but we shall see that the type of vibration has much to do with the method employed. One method is to have the natural frequency of the vibration far beyond the range of engine speeds; the other, to provide sufficient damping to nullify the vibration.

Crankshaft vibration due to elasticity can be divided into transverse and torsional vibrations. The most effective way to eliminate perceptible transverse vibration is to design a rigid crankshaft so that the movements or displacements shall be as small as possible. If the crankshaft is supported by only a few bearings in the crankcase, the size of the shaft must be very large. If many main bearings are used, the shaft can be very much smaller in diameter for a given degree of stiffness. Of course, the greatest number of bearings is obtained when one is placed between each crankpin. For an eight-cylinder-in-line engine, the number of bearings is nine. For the equivalent stiffness of a given size of shaft, with such small spans between supports as nine bearings afford, a shaft of fewer bearings would be inordinately large, and so the same degree of stiffness is not obtained in practice.

A large number of main bearings has also another distinct advantage in respect to transverse vibrations. Aside from the stiffness of the shaft, the vibration frequency bears a relation to the length of the unsupported segments of the shaft, being higher for the shorter spans; that is, all vibration which does not have nodes at the bearings is thus damped quickly, further preventing resonance. As a result of both the small amplitude and the high natural frequency of the nine-bearing crankshaft, the transverse vibration is reduced to such inconsequential effects as to be entirely beyond human sensibilities.

Torsional vibration is generally more complex than transverse vibration, because the number of main bearings has no direct influence on the mode of vibration that may take place. The torsional rigidity of the shaft, and the distribution of the masses attached or connected to the shaft, are the determining factors for a given engine design.

The entire system of shafts, gears and rotating parts comprising the driving mechanism from the front of the engine to the road surface, constitutes a vibrating system under the action of the power impulses. This system is extremely complex and, regardless of what has been said of torsional periods, they may generally be found in the most unsuspected designs. Fig. 1 shows the large number of torsional periods a six-cylinder shaft may be subject to. These periods were determined by the Geiger torsiograph for a six-cylinder engine of foreign design and illustrate the fact that periods exist even though they may be undiscernible.

For a six-cylinder engine, these periods occur when the engine speeds are one-third, one-sixth, one-ninth and the like times the primary natural vibrating frequency of the shaft; for an eight-cylinder engine one-half, one-quarter, one-sixth and the like times the frequency. The primary vibration-frequency of the shaft must always be very much higher than the maximum speed at which the engine is to operate, as synchronism here would be dangerous. The next higher order of vibration should be avoided also, for synchronism usually results in a pronounced disturbance or roughness of the engine. The next higher orders of vibration generally can be detected only by highly trained experts or by special instruments; but, even when they are not discernible, they frequently cause trouble. For instance, chronic valve-spring breakage frequently can be traced back to very slight torsional vibration.

The selection of the general dimensions of the crankshaft for the single-eight engine was fixed so that the fourth-order vibration-period occurred at a speed of about 65 m.p.h. The dimensions obtained were just sufficient to allow for the removal of the piston through the cylinder, and thereby no sacrifice in accessibility was made. At the same time, an engine design was provided that is remarkably unaffected by torsional periods. However, to provide the full protection against the insidious effects of the undetectable higher partials, the vibration damper was fitted. This device damps out the vibration in the incipient stage in a manner similar to that of a pendulum bob released to swing through a viscous fluid such as oil.

The bearing design worked in very well, as a study of Table 2 will show. Figs. 5 and 6 show graphically the loads on the various bearings at 3000 r.p.m. With pres-

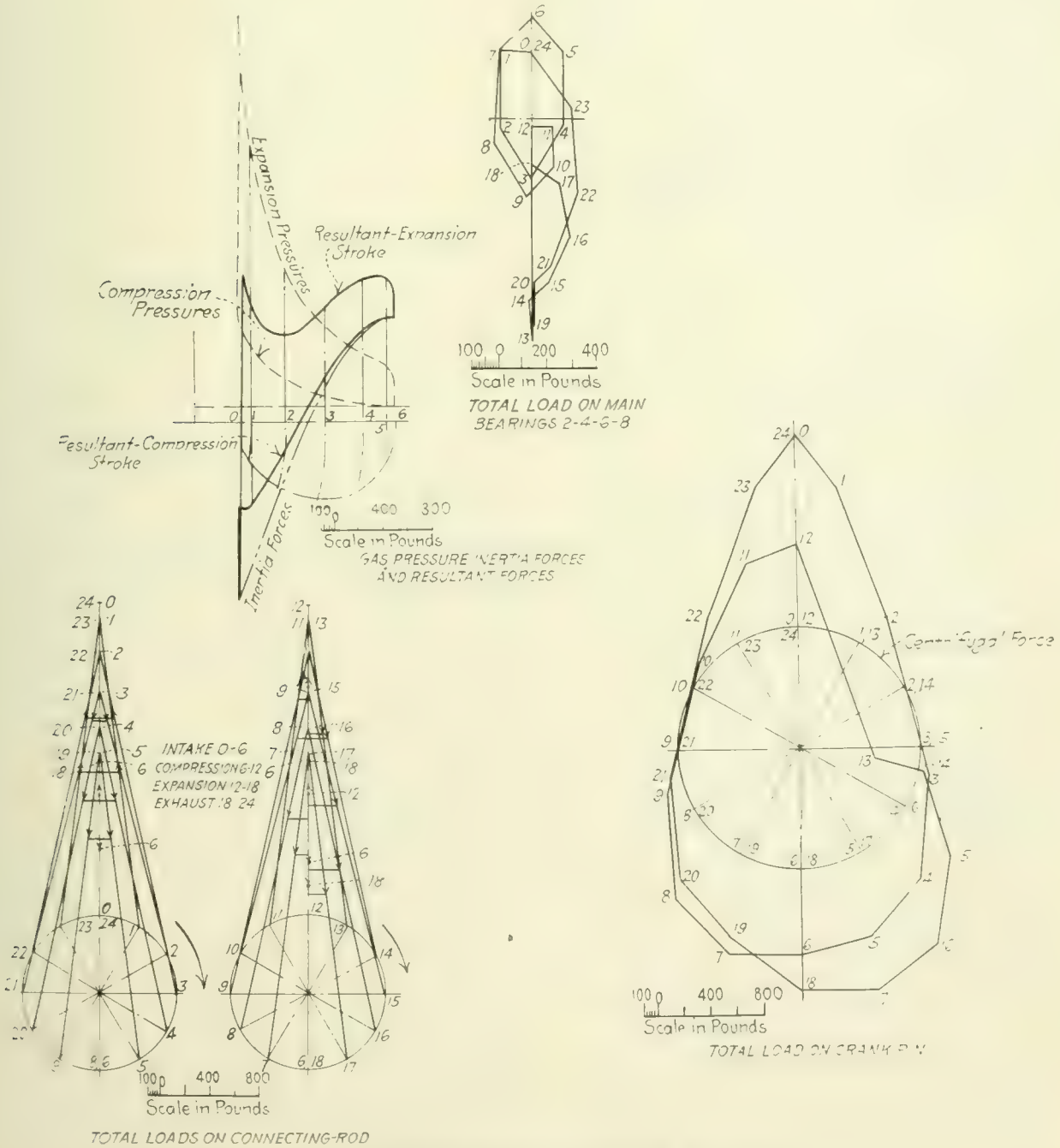
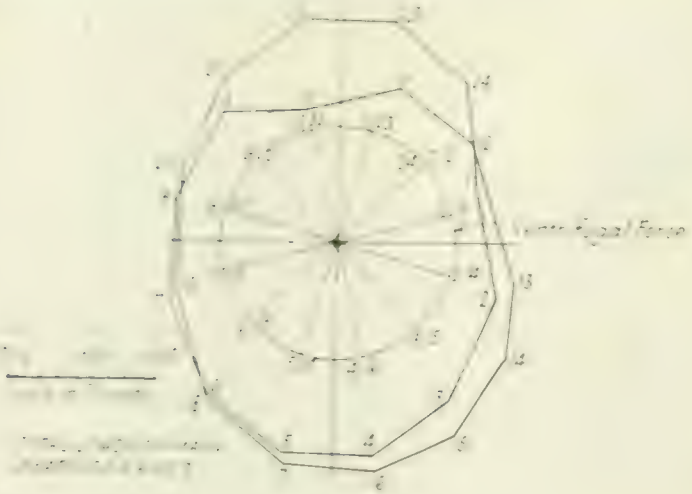
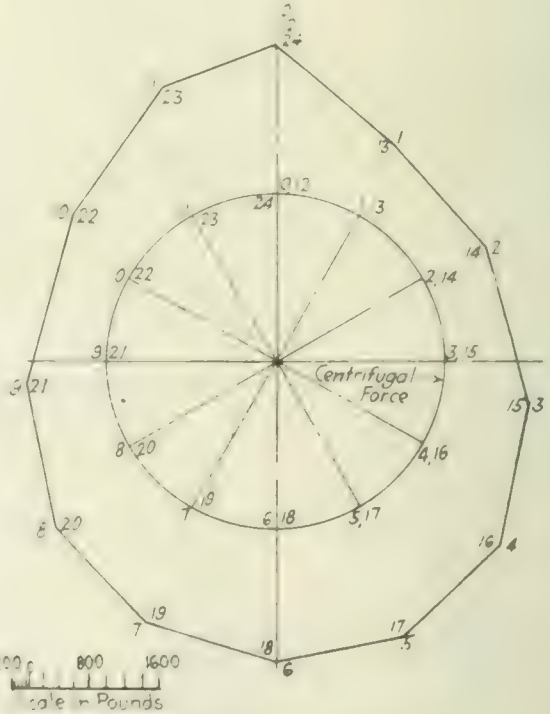


FIG. 5—DIAGRAMS OF VARIOUS PRESSURES AND LOADS

crankpin bearing has been given special attention. An investigation that we conducted about 2 years ago was reported under the title An Analysis of a Point in Crankpin Lubrication,[4] and led to the discovery that the most effective lubrication is obtained when the oil is introduced to the bearing on the side of minimum pressure just previous to explosion. Fig. 7 shows the pressure distribution on a crankpin during the cycle at 600 r.p.m., and also the position of the oil-feed hole in the crankpin; for 3000 r.p.m., the pressure distribution is shown by Fig. 8. As the speed increases from 600 to 3000 r.p.m., the area of greatest pressure gradually moves from the upper side around in a counterclockwise direction to the lower side of the crankpin. Normally, passenger-car engines do not operate at full power below the speed of maximum torque, which is seldom less than from 800 to 1000 r.p.m.





TOTAL LOADS ON MAIN BEARING 5

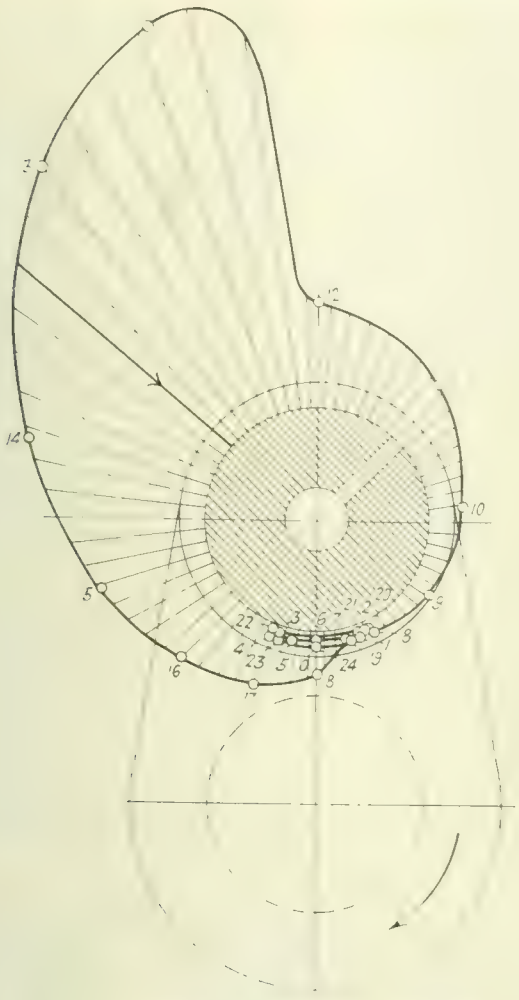


FIG. 7—DIAGRAM OF CRANKPIN PRESSURES AT A SPEED OF 600 R.P.M. AND FULL LOAD

GAS DISTRIBUTION

The original premise that eliminated the more complicated engine designs in favor of the eight-cylinder-in-line design naturally implied that a single carbureter must be adequate and must function properly. At first, the problem of distribution appeared to be a very difficult one because of the length of the passages to some of the cylinders. Uniform distribution is, at high speeds, difficult in most forms of multi-cylinder engines, and the distance to the remote cylinders of the eight-cylinder-in-line engine appeared to complicate the problem even more. However, upon a thorough study of a problem, what often appears to be a fundamental disadvantage is found not to be fundamental at all, but merely a disadvantage under special conditions. When the conditions are changed, the disadvantage often works out to be a decided advantage. This was the case with the distribution for the single-eight engine.

After an immense amount of research and experimental work, we were able to formulate a general rule that may be applicable to straight-line eight-cylinder engines, but this rule, however, appears to be fundamental. This rule is to make the gas passages as short and direct as possible, and have the engine timing arranged so that the inertia of the moving column of gas can be utilized to overcome the unequal suction in different parts of the passages, particularly when directional differences of flow exist; and, further, to utilize the maximum inertia of the gas column to aid the movement of gas to the cylinders remote from the carbureter, also supplying enough heat to the mixture to offset the radiation of the

TABLE 2—SUMMARY OF CRANKSHAFT BEARING DATA FOR MODEL NOS. 136 AND 143

	BEARINGS					
	Crank-pin	Front Main (1)	Intermediate Main (2, 4, 6 and 8)	Intermediate Center Main (3 and 7)	Center Main (5)	Rear Main (9)
Journal Lengths, Measured Overall on Shaft, in.	$1\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{3}{16}$	$1\frac{13}{16}$	$1\frac{13}{16}$	$2\frac{1}{2}$
Journal Outside Diameters, in.	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{1}{8}$
Bearing Lengths Measured Overall on Box, in	$1\frac{1}{2}$	$2\frac{9}{16}$	$1\frac{9}{64}$	$1\frac{41}{64}$	$1\frac{53}{64}$	$2\frac{1}{8}$
Net Effective Bearing Lengths, in	1 263	2 475	0 905	1.406	1 656	2 183
Net Effective Projected Area, sq. in.	2.685	5 810	2.150	3 340	3 930	5 180
Maximum Bearing Loads, lb. {Total	2,510	2,400	880	3,205	4,400	2,400
{Unit	935	413	409	958	1,120	463
Mean Bearing Loads, lb. {Total	1,540	1,900	357	2,645	3,750	1,900
{Unit	474	327	166	792	955	367
P-V Values, at 3000 r.p.m. lb.-ft. per sec.	16,000	10,200	5,200	24,600	29,600	11,400

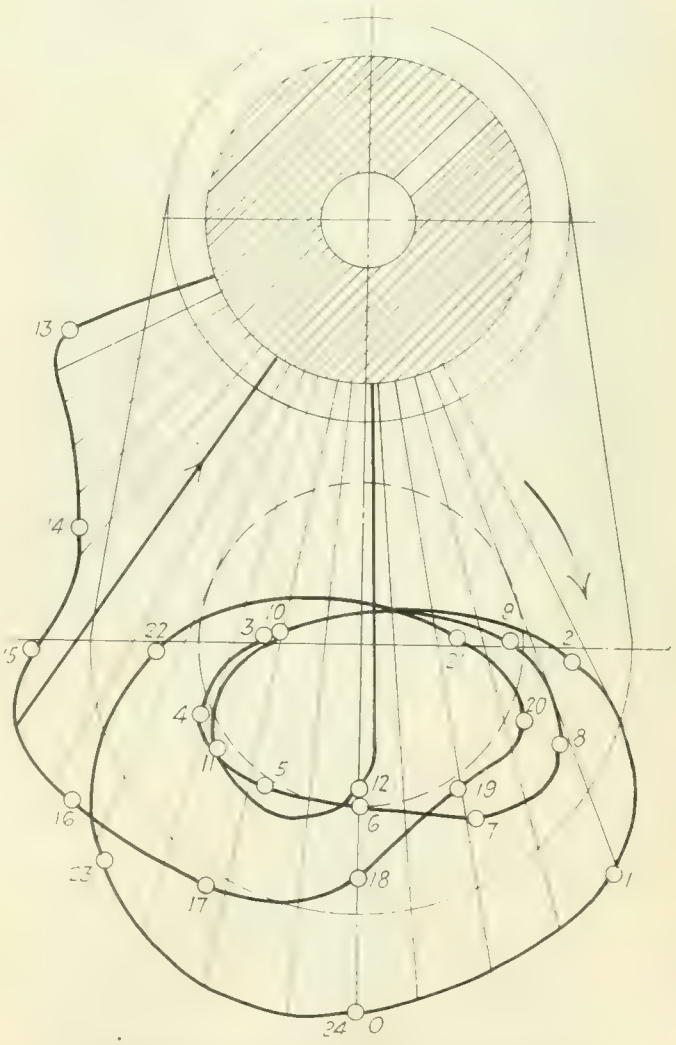
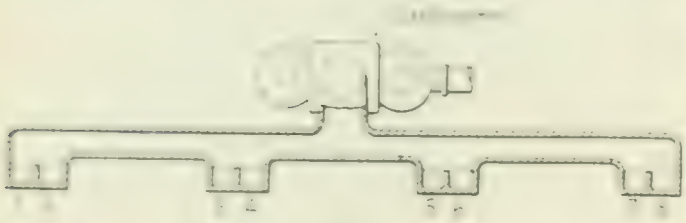
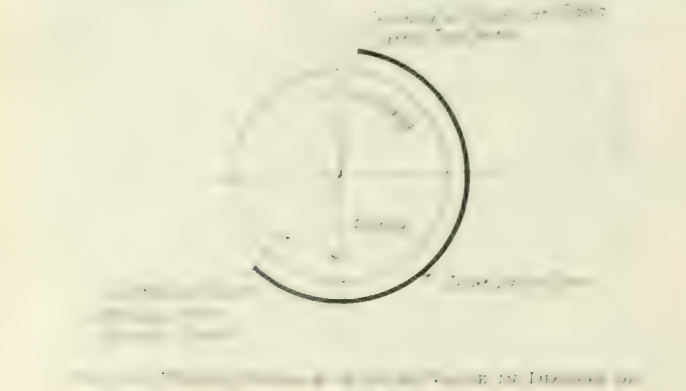


FIG. 8—CRANKPIN PRESSURE DIAGRAM AT A SPEED OF 3000 R.P.M. AND FULL LOAD



leading from the carbureter; this is midway between cylinders Nos. 4 and 5. With any timing whatsoever, it is evident that the first cylinder firing in either half which follows immediately a cylinder of the other half firing must cause a change in the direction of the gas flow, from front to rear or vice versa. In the firing order 1-8-2-5-3-6-7-4, that we adopted, such a reversal takes place in the interval between the suction strokes of cylinders Nos. 2 or 7 and the firing strokes of cylinders Nos. 5 or 4 taken respectively. A study of one of these reversals reveals much.

Let us say that cylinder No. 3 is on the suction stroke. After the piston has reached its maximum velocity near mid-stroke, the gas column is moving with nearly its maximum velocity and hence possesses considerable inertia. At 100 deg. of crank travel of No. 2 cylinder, the inlet-valve of No. 5 cylinder begins to open, but this cylinder is very near the carbureter and hence its suction is almost immediately active in diverting a quantity of gas toward cylinder No. 5. As the depression of cylinder No. 5 increases, a greater amount of gas is diverted in its direction while the inertia of the gas column moving toward cylinder No. 2, plus the decreasing suction, maintains a proportionate division of the quantity coming from the carbureter. Slightly after cylinder No. 5 reaches the point of maximum piston velocity, the valve of cylinder No. 2 closes, thus making the suction of cylinder No. 5 fully effective over the short distance to the carbureter. The relative distances involved and the compensating effect of the inertia of the gas thus produces a condition in which a practically equal distribution of mixture takes place between these two cylinders.



Next, we have one of the two most remote cylinders firing, No. 8 cylinder. At the conclusion of induction to No. 5 cylinder, the complete change in the direction of the flow has been effected, and some of the mixture has already passed beyond this cylinder, due to its inertia in making the bend to cylinder No. 5. Therefore, the only work of induction that cylinder No. 8 has to perform is to draw the already moving column of mixture to its end of the passage, through the intervening length of manifold of only two cylinders. This intervening length is desirable because, otherwise, if cylinder No. 8 followed cylinder No. 7, the inertia of this long column of gas would be so great as to cause loading of the end cylinder.

Cylinder No. 6 follows next in order. Here we have only one intervening cylinder. The double compensation, due partly to the overlap in valve opening and the passage lengths involved, prevents loading of cylinder No. 8 and, at the same time, allows cylinder No. 6 to get its full share of mixture.

Cylinder No. 7 follows cylinder No. 6, and it would appear that cylinder No. 7 would get more than its share; but the compensation involved in the reversal of direction that occurs during the latter part of the valve opening, caused by the opening of the valve of cylinder No. 4, causes an equal distribution again. Of course, the difficulty caused by condensation might prove serious if it were not handled properly, but this is overcome by the combined use of a fuelizer and exhaust-manifold heat.

Fuelizer Operation

Fig. 11 shows the fuelizer installation. In operation the fuelizer heats the gasoline and the air from the carbureter so that the mixture enters the cylinders as a dry gas rather than a combination of air and liquid particles. This is accomplished by shunting a small fraction of the gasoline and air mixture passing to the engine through the throttle-valve shaft into a passage in the manifold that leads to the burning chamber of the fuelizer. This mixture is ignited by the spark-plug in the side of the burning chamber of the fuelizer and burns with a steady flame, which can be viewed through the inspection glass on top of the fuelizer. The flame heats the burning-chamber walls and then the hot burned gas mixed with the charge going to the engine from the carbureter. The application of heat to the ingoing mixture improves its gasification greatly, which is particularly important at the lower throttle-openings, at which time the fuelizer supplies its maximum heat. With an increasing engine speed, the fuelizer heat gradually diminishes and, at high speeds where this heat is no longer required, the fuelizer automatically ceases to function.

The total quantity of gasoline for a given setting of the carbureter is little affected one way or the other by the gasoline burned in the fuelizer, but the fuelizer makes possible the use of a mixture that greatly increases the economy. In this way when the manifold is designed properly, when the firing order is arranged to take advantage of the inertia effects of the gases and when sufficient heat is supplied to maintain a dry mixture, the uniformity of distribution is as nearly effected ideally as it is practically possible to make it.

Cylinder and Valve-Gear

Of necessity the cylinder and valve-gear layouts are complemental. The engine thermal and volumetric efficiencies are dependent very largely on the design of the

clearance or combustion space of the cylinder. The design of the combustion space is influenced greatly by the location of the valves referred to the cylinder proper. Fundamentally, the radiating surface of the combustion-chamber should be as small as possible for the given volume of the clearance required. Also, the gas flow into the cylinder should be direct. For the L-head cylinder, this is accomplished in part by placing the valves close to the cylinder bore. With direct-acting tappets, the camshaft must be placed in line with the valve; this brings the camshaft close to the center of the engine and, to provide clearance for the lower ends of the connecting-rods, the crankshaft must be placed far enough below the camshaft. This requires long connecting-rods and, therefore, makes for a high and consequently, for a heavier engine.

Using rocker levers allows the axis of the camshaft to be placed farther from the center of the engine and, therefore, permits a more compact and lighter engine construction. For a given diameter of camshaft, better shaped cams are obtained for a given valve-lift and acceleration; that is, the static component, equivalent to the side-thrust, of the cam-force acting on the rocker-arm, is of a small proportion to the total lifting force. The reason is that the base-circle diameter is larger in proportion to the lift of the cam. This static component is reacted at the rocker-pivot, which is an oscillating pin bearing and generally is considered superior to bearings sliding along straight elements. This can be explained by analyzing the relation of forces acting on the rocker-lever and the ordinary follower. In Fig. 12, the

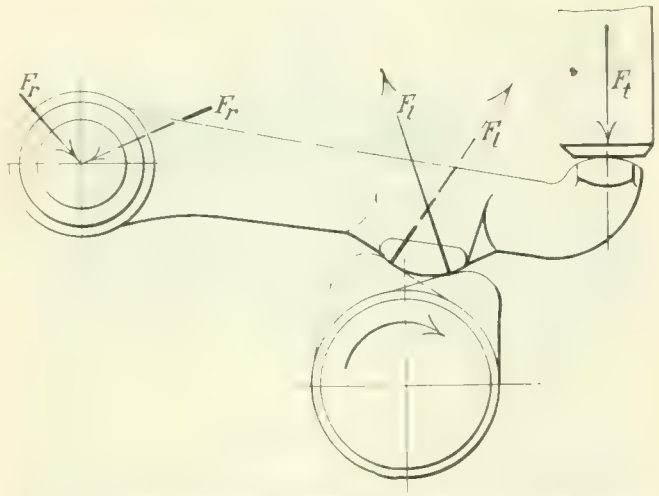


Fig. 12 - Diagram of the Forces Acting on the Rocker Arm

cam is shown turning clockwise and lifting the rocker-lever against a force F_t at the tappet. The lifting force required is, say, F_l, acting in the direction shown.

The reaction at the pivot is shown by the force F_r. As the cams revolve farther, the direction of the force F_l approaches the vertical, with a consequent approach to the vertical of the reacting force F_r. At the maximum lift, these forces are vertical and, with further cam rotation, the forces incline in the other direction again

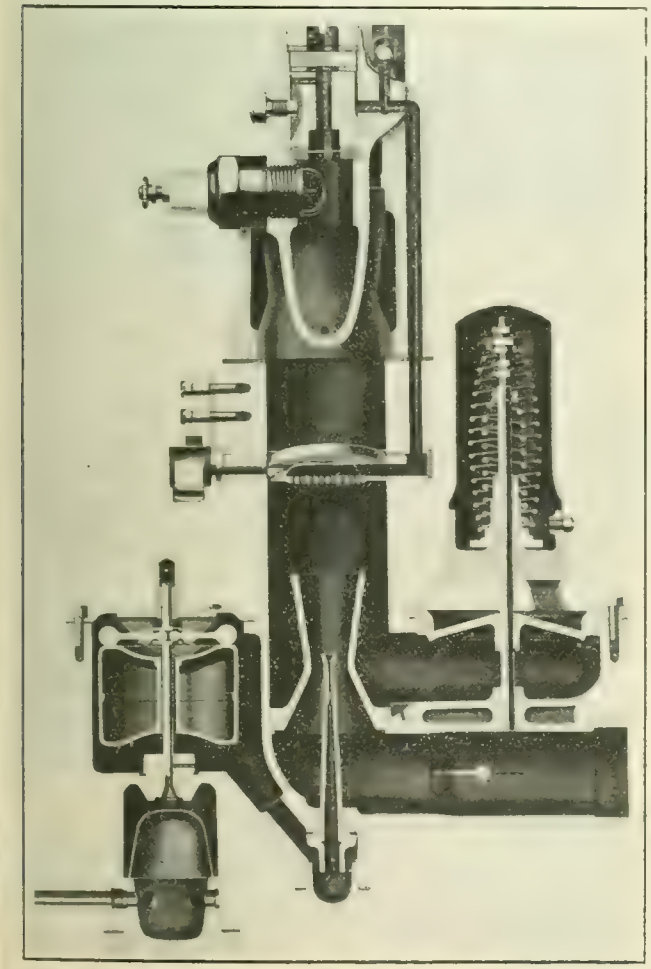


Fig. 11—Sectional View of the Carbureter and Fuelizer

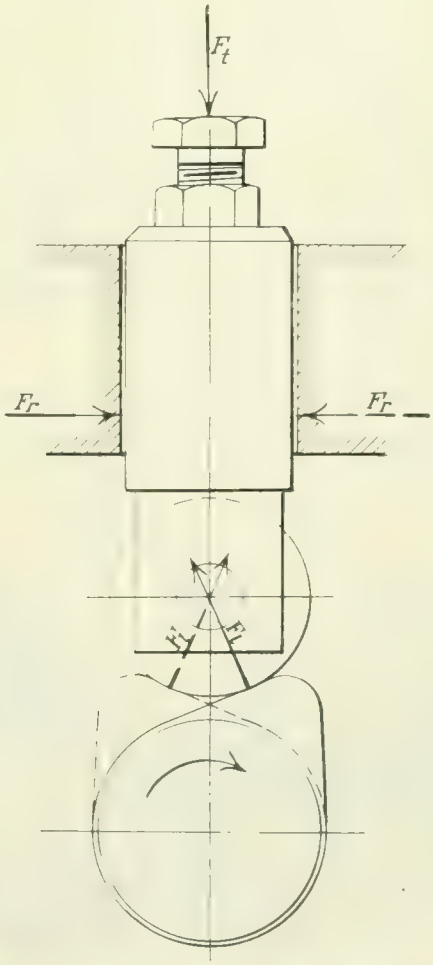
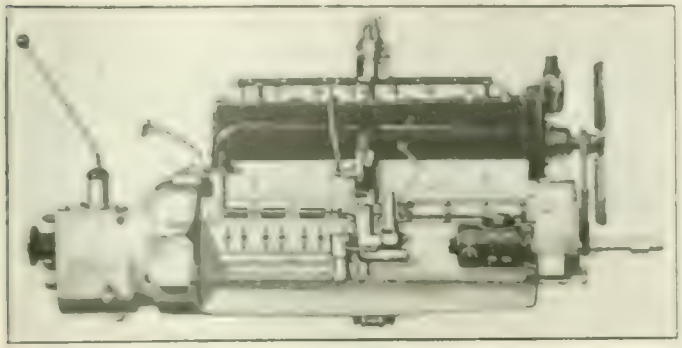


Fig. 13—Diagram Showing the Forces Acting on an Ordinary Roller Tappet

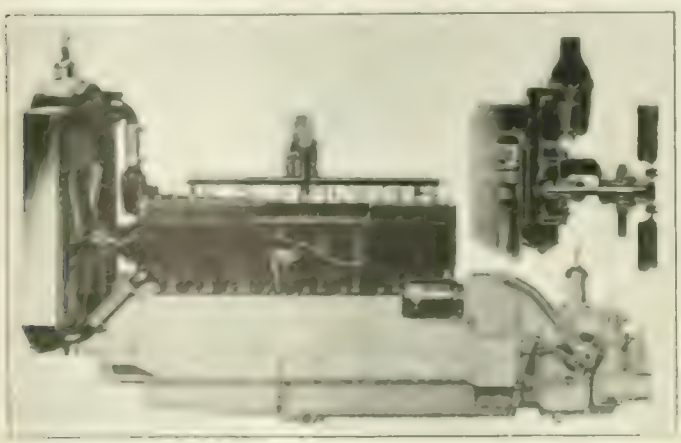


toward the vertical at the closed position. Thus, the direction of the reacting force oscillates about a relatively narrow area of the pin bearing. This action is accompanied by no diametral change of the clearance and without impact. With the ordinary roller tappet shown in Fig. 13, there is a take-up of the clearance across the diameter with every change of the direction of the side-thrust. At high speeds, with worn guides, the impacts produced cause considerable noise. Thus, with the cylinder and valve-gear construction that has been adopted, we feel that ordonnance, a right arrangement of parts to produce the best effect, has been accomplished.

Arrangement of Accessories

To carry out the original plan of simplicity and accessibility, particular attention is given the location of the various engine accessories. The ignition distributor is placed above the cylinder-head and is driven through spiral gears from the camshaft. The same shaft that operates the distributor also drives the oil-pump, which is located in the crankcase. The electric-lighting generator is located at the front end of the crankcase on the right side of the engine. The driving sprocket is placed in a triangular relation to the camshaft and the crankshaft sprockets, the three comprising, with the chain, the front-end drive. The starting motor is situated at the left side of the flywheel housing and functions through the conventional Bendix drive and the alloy-steel ring-gear on the flywheel.

The water-pump is located in the front end of the cylinder-block. The water-pump shaft also carries the air-circulating fan, both the fan and the pump being driven by a V-type leather-faced linked belt operating from a pulley on the camshaft. The carbureter is mounted



on the right side of the engine, at the middle of the length of the cylinder. Fig. 14 shows the right side of the powerplant and Fig. 15 shows the cooling system viewed from the left side of the engine. The simplicity of the entire arrangement is evident.

Transmission Design

The construction of the transmission and that of the clutch are shown in Fig. 16. Economy of transmission design depends very largely upon the proper coordination of the gear design and upon the sizes of the shafts and the bearings. This is dependent largely upon the center distance of the shafts being in a proper relation to the capacity of the transmission. The capacity of a gear varies approximately as the square of the diameter and directly as the effective face-width for a given pitch and pressure angle. On the other hand, for a given transmission capacity, the shaft size varies in a direct proportion of the length between the supports or bearings and inversely as the fourth root of the center distance. The

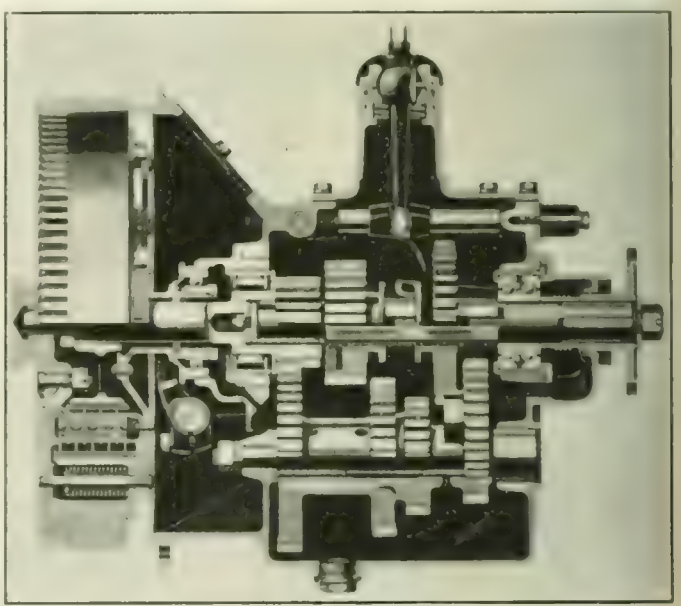


Fig. 16—The Transmission and the Clutch

capacity of the bearings must increase in an inverse proportion to the center distance between the shafts.

The length of the transmission case increases in a multiple of the increase in the face-width, which multiple is equal to twice the number of sliding gears in the transmission. Therefore, for a given capacity, it is apparent that the length of the transmission will increase at a more rapid rate than the transverse dimension that depends on the center distance. Incidentally, the stresses in the transmission case increase with a decrease in the center distance; therefore, the stiffness of the case, which has an appreciable effect on the running quality of the gears, also is associated with the center distance. The most economical coordination cannot be obtained as yet by any formulated rules but only after a study of specific conditions.

Durability of the gears is, within certain limits, very slightly affected by the pitch of the teeth. Consequently, no special advantage results from designing the teeth for bending strength alone. As long as ample provision is made against breakage, the use of coarse-pitch teeth is undesirable. In the study of the gear design, the pitch, the number of teeth in simultaneous contact,

the specific sliding factors and the pressure angle are elements requiring consideration. In general, tooth failures rarely occur in present-day practice. The compressive strength between two teeth in contact under load seems most important; that is, the surface pressure of the opposing curved tooth-faces must not exceed the endurance limit of the material because, otherwise, surface fatigue will take place eventually and cause changes in the tooth-form that greatly impair the running quality or quietness of the gears.

The compressive strength also has a direct influence on the preservation of the lubricating film between the teeth because, the greater the surface pressure is, and the smaller the relative velocity of sliding of the teeth is, the more difficult it is to maintain the oil-film. The relative sliding speed is zero at the pitch-line and, except for the sliding produced by the minute deformation of the surfaces in the contact, pure rolling of the teeth occurs. At this point the oil is squeezed out easily if certain unit pressures are exceeded.

Wearing Qualities of Gears

We can compare the wearing qualities of gears made of the same material identically heat-treated by the modified Hertz formula

$$K = P\,[(1/r_1) \pm (1/r_2)] \div b \sin 2\phi \qquad (1)$$

where

ϕ = the pressure angle
b = the face width
K = a factor proportional to the maximum compressive stress
P = the total tangential load on the teeth
r_1 = the pitch radius of the pinion
r_2 = the pitch radius of the gear

This formula applies strictly only within the compressive elastic-limit of the material, but it is comparative for stresses exceeding this limit. It has been found that, for a limited number of applications of load, the value of K may greatly exceed the permissible value for continuous operation of equal durability. For this reason, the values of K may vary over a considerable range for the different speeds, being lowest for the constant-mesh gears and greatest for the reverse gears. The tooth load P, computed from the maximum engine-torque, is used in making comparisons and the permissible value of K depends very much on the materials and the heat-treatments for steels, larger values generally accompanying greater hardness.

Wear of the gear teeth is also a function of the relative sliding that takes place between the surfaces of contact, while quiet operation depends to an appreciable extent on the number of pairs of teeth in simultaneous contact; or, upon the overlap between successive engagements. These two elements conflict in tooth-forms that have the addendum equal to the dedendum.

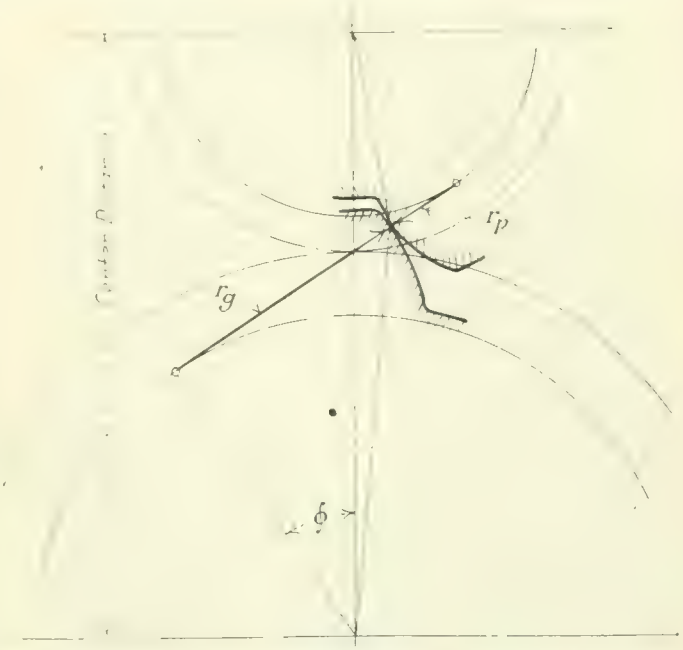


Fig. 17—Diagram for Determining the Radius of Curvature of the Involutes at the Point of Contact of the Gear Teeth

The relative sliding is also a function of the pressure angle and may be expressed by the formula

$$\left.\begin{aligned} Q_p &= 1 - r_g/r_p R \\ Q_g &= 1 - r_p R/r_g \end{aligned}\right\} \qquad (2)$$

where

Q_p = the relative sliding for the pinion
Q_g = the relative sliding for the gear
R = the velocity ratio
r_g = the radius of curvature at the instantaneous point of contact for the gear
r_p = the radius of curvature at the instantaneous point of contact for the pinion

Reference should now be made to Fig. 17. The number of teeth in contact is

$$N_c = \tan\phi\ (n_1 + n_2)\ (r_b - r_e)/2\pi \qquad (3)$$

where

N_c = the number of teeth in contact
n_1 = the number of teeth in the driving gear
n_2 = the number of teeth in the driven gear
ϕ = the pressure angle
r_b = the radius of curvature of the tooth at the beginning of action
r_e = the radius of curvature of the tooth at the end of action

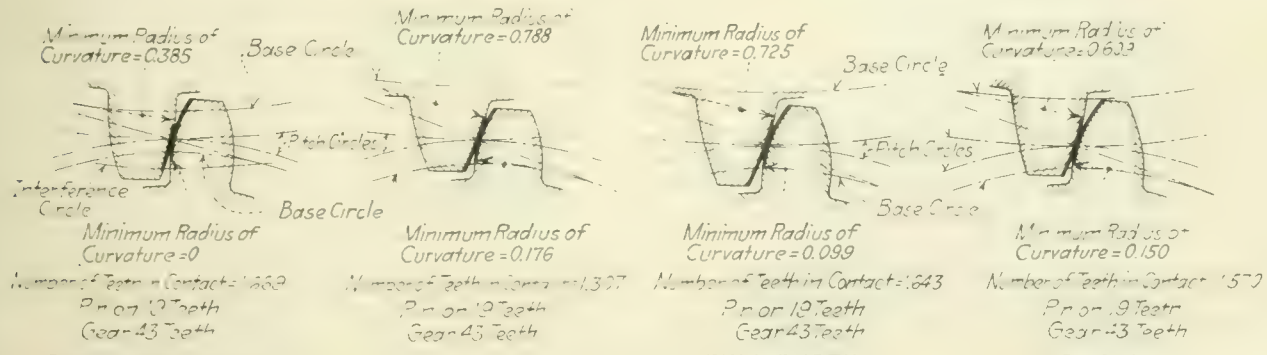
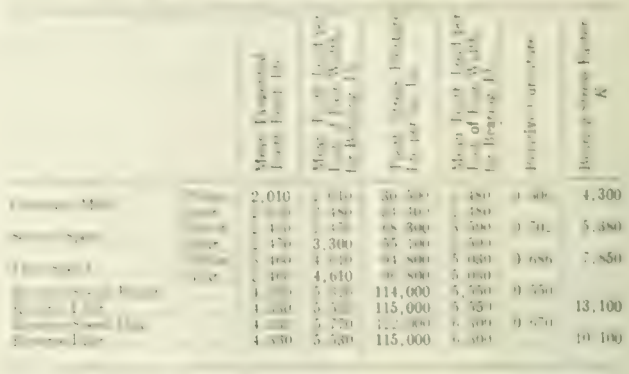


Fig. 18—A Comparison of Various Tooth Profiles

TABLE 3—TRANSMISSION-GEAR DATA

TABLE 4—CALCULATED STRESSES



By formulas (1), (2) and (3), the tooth-form can be designed to give the tooth action desired.

The value of r_2 at the base circle is equal to zero and, if tooth action begins here, the relative sliding will be greatest. Hence it is important for two reasons to start the tooth action on the involute curve somewhere above the base circle, where r_2 will be of finite length: to maintain a minimum rate of sliding and to maintain the curve that is easily generated. It obviously is impracticable to generate with accuracy a curve that has a radius of curvature equal to zero. Figs. 18 and 19 show the improvement that can be effected by varying the specific sliding, the number of teeth in contact and the durability factors. Tables 3 and 4 give the particulars relating to the single-eight transmission-gear design.

Accuracy and finish are also elements contributing to durability and running quality. Generally, the more accurate the profiles are and the smoother the finish at the beginning of service is, the greater the durability against wear will be. So far, finish-grinding the tooth profiles offers the most accurate method of reproduction. We have adopted this for regular production.

Fundamental Requirements of Brakes and Steering

Faster driving speeds and greater accelerations require more rapid and more effective speed reduction. In large cars of high power, the maximum degree of retardation for two-wheel brakes has been reached and, therefore, to improve braking beyond this point, four-wheel brakes must be employed. Good four-wheel brakes require careful study in their design and must be carefully made, for hazardous results follow if either the design or the workmanship is subordinated to cost or if [illegible] considerations due to insufficient study. The fundamental requirements are summed up as follows:

(1) Action of the brakes must not interfere with steering

(2) Brakes must be equalized properly at all times

(3) Brakes must operate with ease and directness

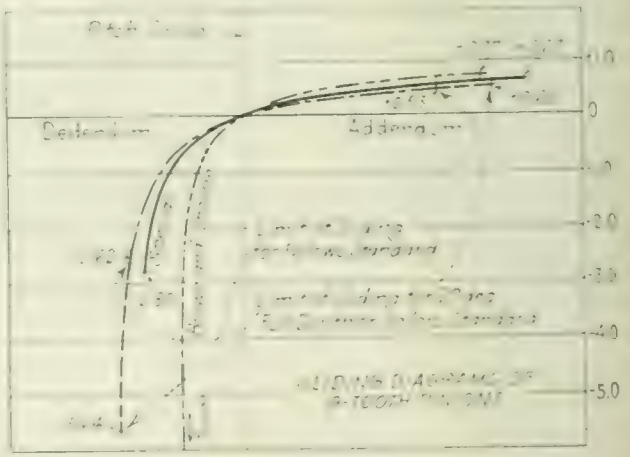
(4) Steering must be comfortable

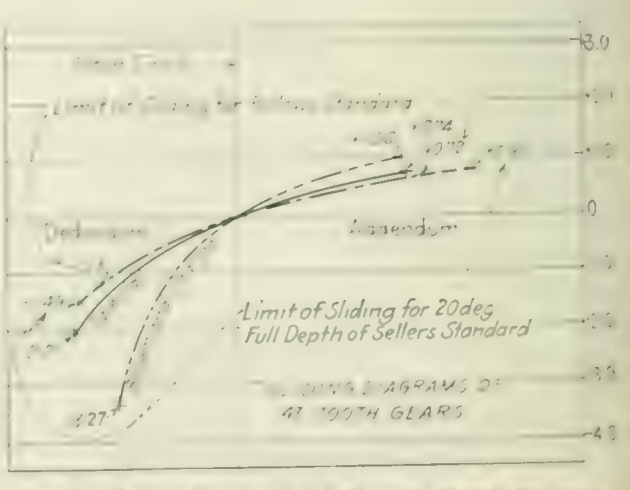
(5) Construction of the brakes and the front axle system must be positive and dependable

In order that the action of the brakes shall not interfere with steering, all forces set-up by the action of the brakes must have little or no tendency to swing the wheel and the steering-knuckle about the axis of the knuckle-pivot. For, if this tendency to turn the wheels out of their path of motion is great, they must be restrained either by the balancing action of the opposite wheel or, when this is absent, by the friction in the steering gear and even by muscular effort on the part of the driver. The [illegible] of such a condition are obvious. When the axis of the knuckle-pivot intersects the center of the tire contact with the ground, the steering tendency is reduced to the minimum.

To explain the action that braking forces have on steering, the following analysis is given. A correct analysis cannot be made based on the assumption that the steering-spindle and the wheel can be treated as a rigid body. The wheel and the knuckle must be treated separately; the forces and their reactions must be determined for each. Another element that has been the cause of considerable confusion is the failure to distinguish between the different kinds of resistance that can occur between the tire and the road. This is absolutely essential to a correct analysis of the problem.

For a car with a high degree of freedom for the rotation of the road wheels, one having anti-friction bearings and moving in a straight path on a horizontal plane which, in a practical sense, means moving straight ahead





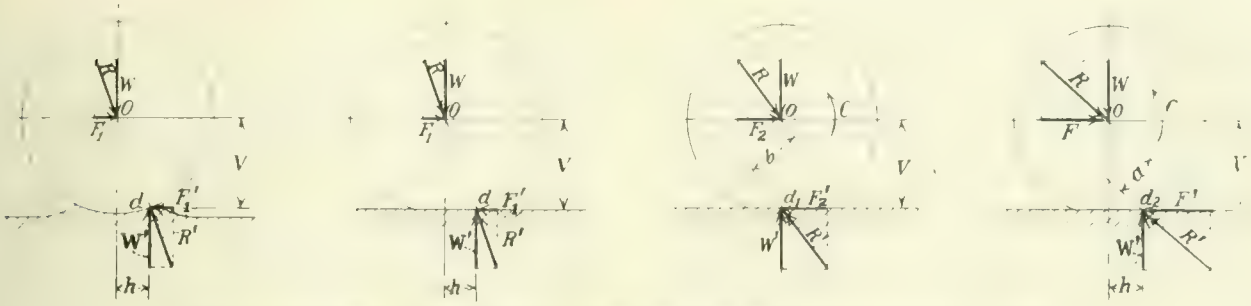


FIG. 20—DIAGRAMS OF THE VARIOUS FORCES INVOLVED IN THE ROTATION OF A WHEEL

on a level road free from deviating forces such as may arise from ruts, the resistance to the motion of the wheels by the road is due to the rolling-resistance and has a definite value for any combination of tire and road conditions. With the car again in rectilinear motion as before, but with the freedom for the rotation of the wheel sufficiently reduced as by locking the wheels with the brakes, we have the condition of the tire sliding on the road. The resistance to motion is then due to sliding friction which, for the same conditions of the tire and the road surface in contact, is many times greater than the rolling-resistance, in some cases being more than 100 times greater.

A third condition may occur in which the resistance to motion may be a maximum. Assume, as before, the car in rectilinear motion and the front-wheel brakes gradually applied until they become locked. At any point in this motion, while the wheels are turning, the resistance to their motion by the road is due to a combination of rolling-resistance and static friction, the amount of resistance due to static friction depending on the resistance to the turning of the wheels by the brakes, becoming a maximum on hard road surfaces just at the instant the wheels begin to slide on the road. On certain soft road-surfaces, the resistance may be a maximum after the wheels are locked. In general, the coefficient of static friction is greater than that of sliding friction but, as actual quantitative values are not essential to this discussion, we may even assume them to be the same. It is absolutely essential to recognize that, qualitatively, they are alike and different from the rolling-resistance.

That the total resistance to motion becomes markedly decreased when the wheels become locked is a common experience to motorists, especially on wet pavements. When the wheels begin to slide, the car seems to go right on, the rate of slowing down being reduced greatly. This is due, partly, to the loss of the rolling-resistance and partly to the lower value of the kinetic or sliding friction.

WHEEL FORCES AND ROLLING-RESISTANCE

In regard to the forces that act on a wheel to overcome rolling-resistance, let us consider a wheel, as in the left half of Fig. 20, in uniform motion on a horizontal plane and overcoming rolling-resistance. The theory of rolling-resistance is based on the assumption that the surfaces in rolling contact undergo a certain amount of compression at the place of contact; hence, the effect is the same as if the roller were continually being moved out of a hollow or up on the edge of a flat on the periphery. If the road is soft compared to the roller, the effect will be that of moving out of the hollow; if the rim of the roller is very soft, as is true of an automobile tire when compared to the road, the effect is that of moving up on the edge of a flat.

A certain force, say F_1, applied at the center O of the wheel is necessary to roll the wheel at a uniform speed. The weight W also acts through the center of the wheel.

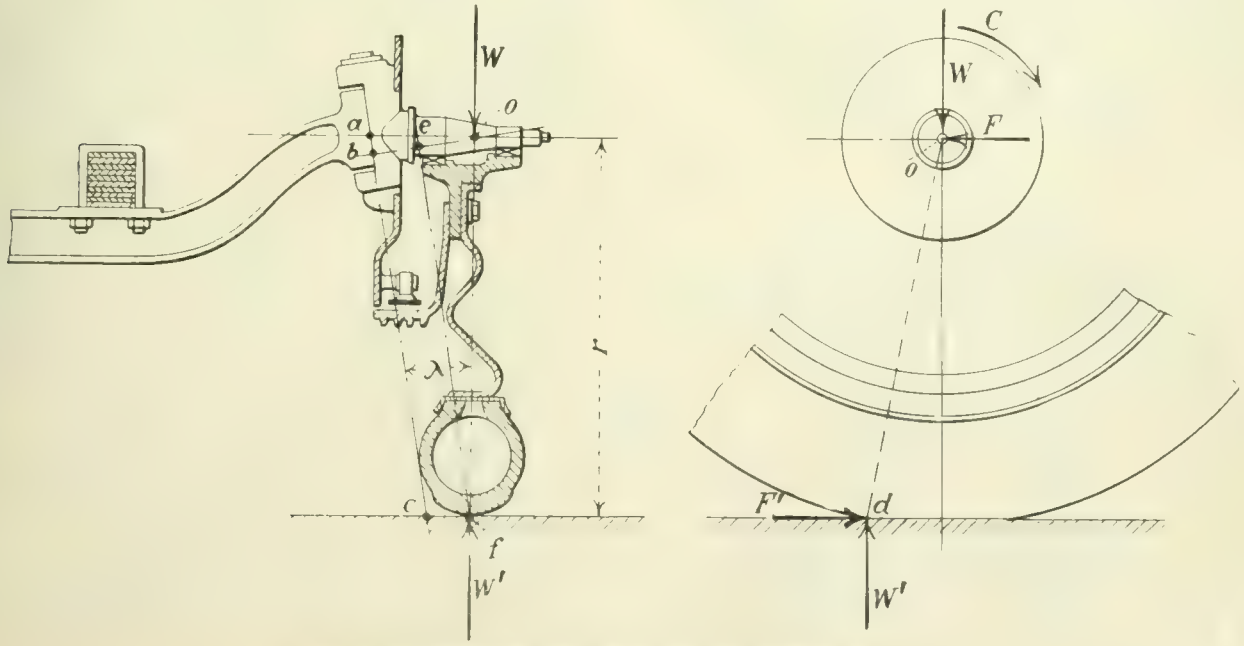
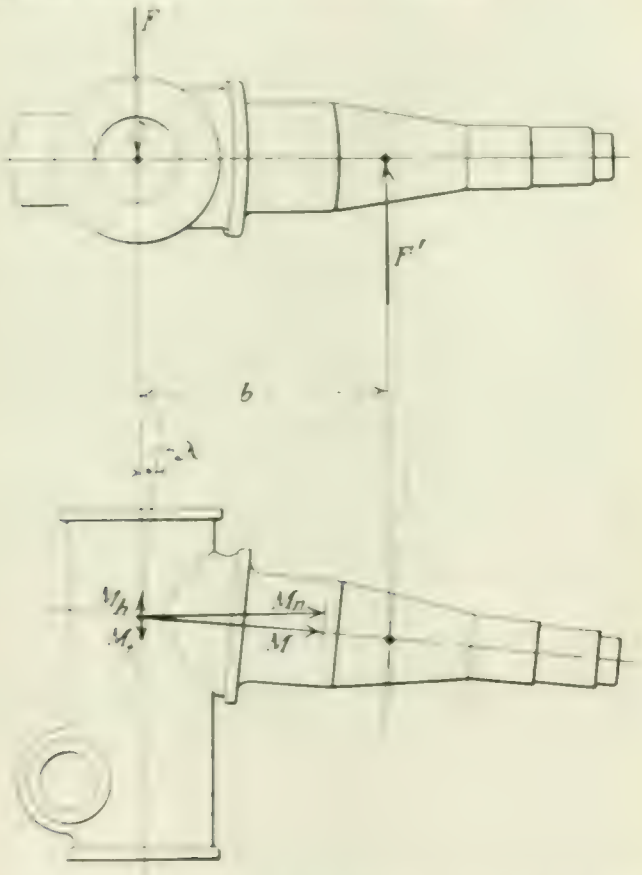


FIG. 21—DIAGRAM OF THE FORCES IN THE STEERING-KNUCKLE

The resultant F_r will, therefore, act through the same [illegible] At some point d, where its line of action strikes the ground, F will be balanced to an equal and opposite force W, which is the resultant of all forces acting on the tire at the road surface. Since we have a balanced system of forces, the moment of W about the point d equals the moment of F about the point d and thus the force F_r, or the total rolling-resistance, can be expressed in terms of the weight on the wheel. This is often spoken of as the coefficient of rolling-resistance and is given in various units such as pounds per ton or pounds per pound. Inasmuch as the action and the reaction between the wheel and the steering-spindle must be equal, the wheel can be removed and replaced by the forces W and F acting through the same point on the spindle. This will be done throughout the following analysis.



[illegible]

Forces for Locked Wheels

In regard to the forces[4] for locked wheels sliding on a horizontal surface, let us consider the wheel shown in the right central view of Fig. 20 as sliding without rotation on a horizontal surface at uniform speed. Here, as distinguished from the rolling-resistance, the sliding friction acts normal to the resultant of the forces causing pressure between the two bodies in contact and tangent to the surface of contact. If F_s is the force that, when applied to the center of the wheel, is necessary to slide the wheel at a uniform speed, we have a moment about the point d that must be resisted by an equal and opposite couple if the system of forces is to be in equilibrium. In the case of wheels locked by brakes, this couple C must be equal to the resistance to the turning of the wheel about its center by the friction of the brakes. The force F_s becomes a maximum when the sliding velocity is zero. This is the static resistance; hence, the couple C also becomes a maximum. When the brakes are applied to a rolling wheel, the maximum value of F_s is a maximum just before the wheel becomes locked and is equal to the resistance due to the static friction. If we remove the wheel from the spindle and replace the forces W and F and the couple C acting on the spindle, the system of forces will not be disturbed.

Analysis for Mixed Resistance

When the wheel is rolling on a horizontal plane and a tendency is exerted on it in such a way as to offer resistance to rotation, the resistance to uniform motion is a mixed resistance due partly to the rolling-resistance and partly to the static friction. Experiments show that, under this condition, the horizontal force which, when applied at the center of the wheel, is necessary to maintain uniform motion, may be so great as to equal the total weight on the wheel.

Let us consider the wheel shown in the extreme right view of Fig. 20. The horizontal force F is equal to the sum of the rolling-resistance and the static resistance to the wheel. The reactions at the tire will act at the point d_2 off of the vertical center-line so that the couple C, which must be applied by the friction of the brakes to resist the rotation of the wheel, is equal to the moment of static resistance F_s about the point d_2. Here again, the wheel may be removed and the forces acting at O be replaced by equal forces and couples, and the resistance will not be disturbed.

Moment About the Knuckle-Axis[5]

Fig. 21 shows diagrammatically in the left drawing the arrangement of the front-axle construction in which the center-line of the steering-knuckle pivot makes any angle, λ, with the center plane of the wheel. The right portion shows the forces W, F and C acting at the center of the wheel when the brakes are applied. Since the line of action of the force due to the weight on the knuckle lies in the plane containing the axis of the spindle, it has no effect on the moment of the spindle axis. The upper view of Fig. 22 shows a knuckle with the force F acting at the center O which causes a moment M_h about the knuckle-axis. In the lower view of Fig. 22, the couple C offered by the friction of the brakes to turning of the wheels, is represented by the moment axis M. The moment axis is a vector, the length of which is proportional to the magnitude of the couple that acts in a clockwise direction when looking in the direction of the arrow. The moment axis M can be resolved into its components M_n, perpendicular to the axis of the knuckle, and M_t, parallel to the axis. The algebraic sum M_h and M_t is the value of the net moment about the spindle axis. When the axis of the knuckle-pivot intersects the center of the tire contact, the resultant moment[6], M_r, will be minimum and due only to the forces set up by rolling-resistance to the wheel.

Because of the necessity for the tire to accommodate its contact to the road surface, the resultant of the tangential or braking forces on the tire will not always intersect the axis of the steering-pivot with center-

[illegible]

point design; but, under certain conditions, it will act with a small moment-arm about it. However, the theoretical arrangement represents the normal condition and the median from which slight departures may occur in any direction. Experience has shown further that, with this type of steering-layout, the action of the brakes even under abnormal conditions does not interfere with steering.

If, now, the brake-actuating mechanism has a fixed center of motion for the entire front-axle and brake construction, the brakes will be unaffected by the steering when the wheels are turned out of the straight ahead position.

Brake Equalization

Requirement (2), embodying equalization and the distribution of the braking effort, is met in the proper design of the brake-actuating mechanism. There are four combinations in which couples tending to cause side-skidding are formed, while still another combination tends to cause front-wheel skidding that excises, or reduces, the control of steering. The formation of couples can be prevented by maintaining the braking effort on one side of the car always equal to the braking effort on the other side. The greatest number of exigencies can be taken care of when the brakes are equalized universally; that is, when the front pair is equalized against the rear pair and the brakes of each pair are equalized against each other.

The cause of front-wheel skidding lies in the preponderance of the braking effort of the front brakes over the braking effort of the rear brakes. To eliminate this condition, it is necessary not only to equalize the front pair against the rear pair of brakes but also to adjust the leverages so that the distribution of the applied effort is in proportion to the weight of the front and the rear wheels during braking. The ratio of leverages is determined best by experiment. No method of hand adjustment is precise enough; it is more often dangerous, and no method of equalization depending on elastic deformation is adequate to accommodate all the variables. An automatic means should be provided and this, preferably, is some form of differential mechanism.

In the actuating mechanism shown in Fig. 23 that we have adopted, the front and the rear pairs of brakes are each equalized by the differential action of the continuous cable in the cross-shaft and lever-arms. The cam-lever of one brake is connected to each end of the cable. The cross-shaft is operated by an integral lever. Obviously, the pull at each end of the cable must at all times be equal. The front pair is equalized against the rear pair through the chain. The tension at each end of the chain is the same, while the pull on the rear cross-shaft pulley over which the chain passes has a definite relation to the pull on the chain. For instance, if the rear brakes offered no resistance, the pulley would simply move forward and there would be no tension in the chain; consequently, no effort would be applied to the front brakes.

Facility of Brake Action

Considering the fact that the brakes must act with ease and directness, the choice of a source of power for actuating four-wheel brakes is influenced by two fundamental factors; (*a*) the human element and (*b*) the amount of effort required.

Every normal person reacts physically in the same general way to an external stimulus. Repeated conscious effort, even when moderate, soon causes fatigue or discomfort. Therefore, manual operation of brakes would not meet with general approval if the required effort were too great. On the other hand, human exertion under the excitation of an emergency may be several times greater than even a willful conscious effort and, therefore, a dynamic actuating device such as a servo-mechanism might prove dangerous except for expert usage. With remote control, the nicety of operation is not so good, and it is a very desirable characteristic. Direct manual actuation is safer because of the more simple and direct construction that requires only the ordinary care generally given to two-wheel-brake installations. The fact that it has always been more or less difficult, in the case of heavy cars, to provide sufficient leverage without requiring considerable pedal effort, and to maintain sufficient travel for the brake pedal and still have sufficient reserve travel to take care of the wear of the linings, gave the problem of manual operation of four brakes a questionable aspect until the shortcomings of ordinary linkages were determined.

Mechanics of Brake Construction

The critical analysis of the mechanics of conventional brake construction and operating linkages reveals that

(1) All work done by the force exerted on the pedal when it travels through the distance available is expended in overcoming friction or causing elastic deformation

(2) The overall mechanical advantage is practically constant throughout the pedal travel

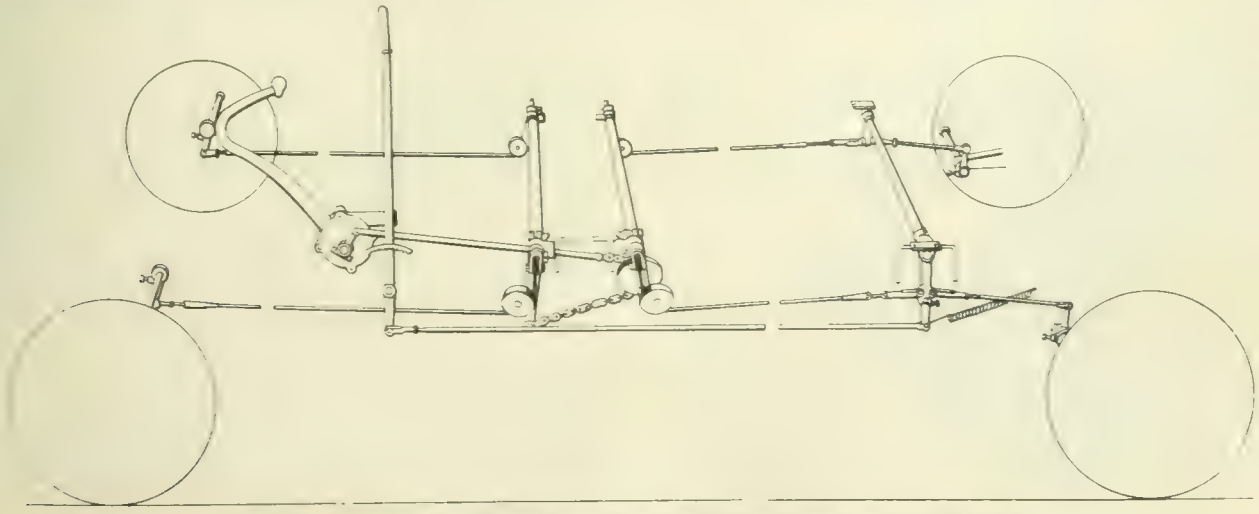


Fig. 23—Diagrammatic Arrangement of the Single-Eight Braking System

(3) Displacements due to deformation of the shoe facings and linkage are unavoidable

(4) Relatively large clearances must be allowed between the shoe and the drum to insure the complete release of the brakes

(5) Allowance must be made for wear of the brake-shoe facings

In explanation of item (1), suppose that no shoe-clearance were necessary, that the rigid metal facings on the brake-shoes and absolutely rigid linkages the total displacement of any particle in the system would be zero, and that, since work is the product of force and distance, no work would be done regardless of the forces involved. From this it is evident that a mechanical advantage could be placed so that tremendous forces at the shoes could be created by a very slight applied force. The problem would then be simple. Displacements that are unavoidable due to extensions, deflections and displacements required for clearance, plus the wear allowances, become serious drawbacks to the use of high mechanical advantages. In fact, the mechanical advantage is limited by these displacements.

This can be illustrated by citing a concrete example. Let

a = the clearance at the middle of the brake-shoe

b = the compression of the shoe-facing plus an amount equivalent to the extension of the connecting linkage at the middle of the shoe

c = an allowance for wear before requiring adjustment at the middle of the shoe

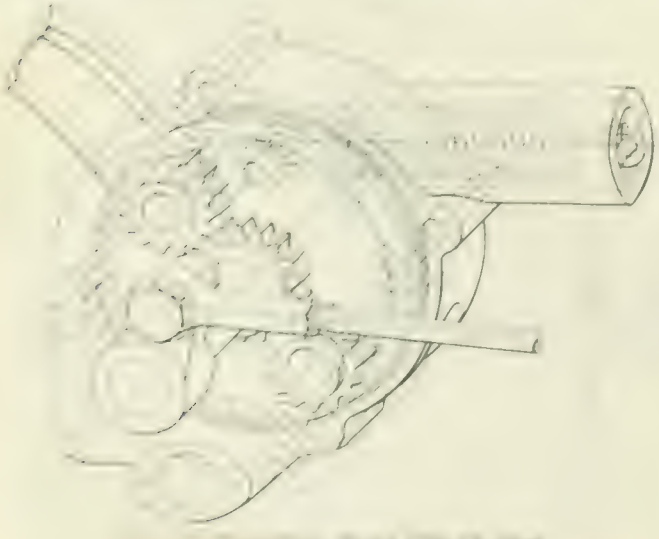
r = the mechanical advantage, foot pedal to brake cam

n = the number of brake-shoes

Then, for a pedal-pad travel of 5 in., we would secure a mechanical advantage of

$$r = 5/n(a + b + c)$$

Thus, for a mechanical advantage of 18, which represents an average value for brakes on the rear wheels only, the equivalent movement that must be allowed for at the center of the brake-shoe is equal to 0.07 in. per brake-shoe; that is, the value of $(a + b + c) = 0.07$ in. If the same allowance were made for four brakes the pressures on the shoe would be about one-half the pressure of two brakes, and the total braking effort would be somewhat less than that of two brakes for a given pedal-pressure. This, of course, is due to the greater friction in the four-brake linkage and to the increased resistance of the larger number of retracting springs. Such a condition would partially defeat the purpose of the four-brake installation and, therefore, a more suitable actuating mechanism is required.



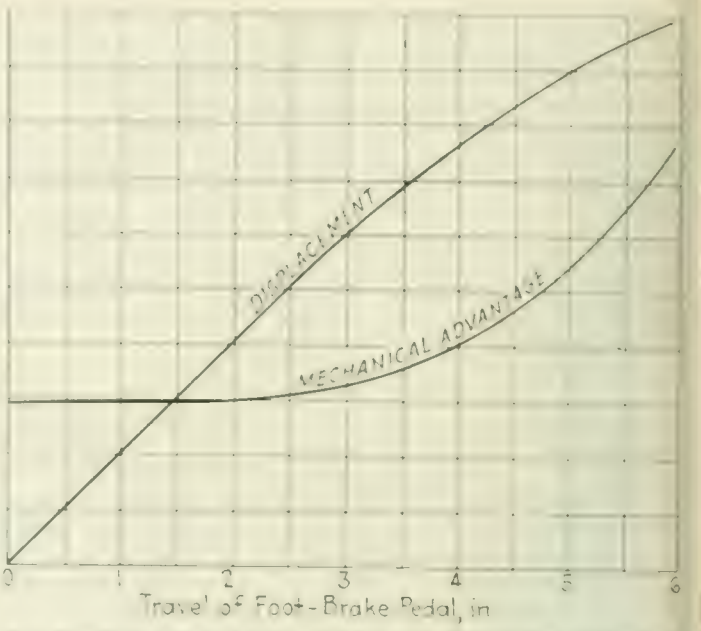


FIG. 25—CURVES OF THE DISPLACEMENT AND MECHANICAL ADVANTAGE CHARACTERISTICS OF THE PACKARD FOUR-WHEEL-BRAKE MECHANISM

The requirements for such a mechanism constitute a varying mechanical advantage such that

(1) The initial clearance of the brakes is taken-up quickly in a small displacement of the brake pedal

(2) No sharp transitions take place; (*a*) making brake adjustment a critical requirement and (*b*) impairing the characteristic "feel" to the driver

(3) There is sufficient latitude so that the operator is warned adequately as to when to adjust brakes

(4) There is a sufficient ratio, but effective braking for a reasonable applied effort

Various types of varying leverage mechanism are available, but all those considered were found to be deficient in some of the requirements that have just been set forth. To meet these requirements, the epicyclic step-up gear was invented. This mechanism is shown in Fig. 24. To illustrate the action of this device, Fig. 25 shows a displacement curve of the brake camshaft-lever movement plotted against the movement of the pedal-pad; the mechanical advantage for various pedal movements is plotted also. It will be noted that both are smooth curves without sudden changes in direction. With such a varying leverage, the clearances and initial stretch and deformations are taken-up in the early part of the pedal travel, during which the leverage is low and the movement rapid. This leaves sufficient travel to operate the brakes with comfortable effort and also provides travel enough to allow for wear of the linings. The deceleration of the car is limited also to the degree that on dry road surfaces it is impossible, with normal adjustment, to lock the wheels even if the pedal is pushed to the floor-boards.

COMFORTABLE STEERING

Comfortable steering is largely a matter of reducing the friction losses in the steering mechanism to a minimum. Friction losses occur in the steering-pivot, in the joints of the cross-tube and the connecting-rod, in the bearings of the steering-gear and in the reduction of the

steering-gear. The fact that these various losses are cumulative makes it important to give careful attention to the design at each of the points where losses occur. When the mechanism is new, these losses are generally lower than they are at any other time during the use of the mechanism.

One of the places of greatest friction loss in front-axle design is at the steering-knuckle pin. Loads on the steering-knuckle-pin bearings are due to a combination of the thrust caused by the weight on the axle and the radial forces due to the beam action of the knuckle. Due to the extremely low rubbing velocities of the surfaces of the bearings, when any displacement of the knuckle occurs it is difficult to maintain efficient lubrication of the surfaces in contact. Further, due to space limitations, the loading is relatively high and, therefore, with bearings that function through the relative sliding of the surfaces, there is usually considerable friction. Friction of bearings, such as ball or roller bearings, that function through the rolling contact of the moving elements, is almost wholly independent of the velocity of the parts. This is particularly true at very low speeds approaching the static condition.

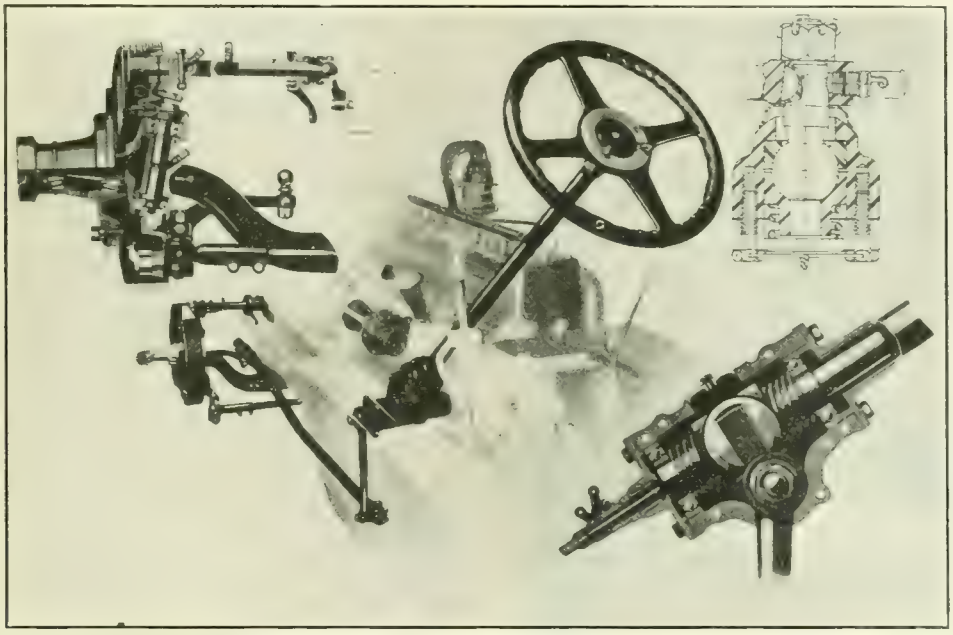


FIG. 26—DETAILS OF THE FRONT-AXLE, STEERING AND BRAKE CONSTRUCTION

AXLE CONSTRUCTION

Fig. 26 shows the construction of the single-eight axle. The lower bearing is a combination radial and thrust bearing while the upper bearing, which is a two-row ball-bearing, takes radial loads only. Very heavy radial loads can be imposed on the lower bearing under conditions such as driving on badly rutted country roads and through side-skidding and steering forces, but these happen with a frequency that is so small in comparison with the frequency of impact in thrust loads that, in determining the load-line of the ball contact, the thrust condition was considered to be most important. Thus, the load-line of the ball contact was made having an obliquity of 30 deg. with the axis of the steering-knuckle pin, and the design of the bearing was worked out so that, under normal static conditions, the maximum stresses produced would not exceed one-fifth of the elastic-limit of the material. On account of space conditions, the double-row ball-bearing is considerably oversize.

The ball joints for the cross-tube are constructed especially to reduce the friction further. In ball joints of conventional construction, it is necessary to make the take-up spring very heavy to enable the forces to be transmitted without too much separation of the spherical seats. The great stiffness of the spring creates a considerable pressure between the surfaces of the ball and its seats and, therefore, produces considerable initial friction. To eliminate this condition, the spherical seats are divided in a plane containing the axis of the cross-tube; hence, the steering forces have little tendency to separate them. Therefore, a comparatively light spring can be used to compensate for wear.

STEERING-GEAR EFFICIENCY

Steering-gear efficiency is largely a matter of design for the screw-and-nut type. The efficiency for motion opposed to the direction of the force acting on the nut is given by the formula

$$e = \tan \gamma / \tan (\gamma + \delta)$$

and, for motion in the same direction, by the formula

$$e = \tan (\gamma - \delta) / \tan \delta$$

where γ is the lead angle and δ is the angle of friction.

Thus, the efficiency approaches the maximum when the lead angle is 45 deg. Typical helix angles used for worm-and-nut steering-gears range down as low at 6 deg. In our design, we have chosen a helix angle of 8 deg. 30 min. which has a steering efficiency of 58 per cent as against 25 per cent for an angle of 6½ deg. The amount of irreversibility, however, is also greater; for the 6½-deg. angle, the efficieny is 7.6 per cent and for the 8½-deg. angle it is 29 per cent. This computed efficiency, however, is based on ideal conditions of the surfaces in contact; that is, upon efficient lubrication.

The conditions under which the steering-gear operates are particularly unfavorable to lubrication. A greasy layer formed by oil or other viscous lubricant has a very low resistance to penetration when the rubbing velocity is very low and, if the pressure between the surfaces is

effect, the screw is squared and the coefficient of friction is increased greatly. The steering gear, under normal driving, is subject to impact loads of considerable magnitude. These, of course, are transmitted through the threads in contact. If the threads bear only in spots, the pressure becomes very great over the small areas. Some lubrication is required by the rapture of the intervening film of oil, but friction remains and the gear is thus difficult to operate. It is practically impossible to machine a screw and nut to fit with all the thread surfaces in contact and yet make them fit so snugly that there is no end play.

To insure effective lubrication and to eliminate end-play, which is undesirable for many reasons, we have adopted the following construction: The screw is first made very carefully to close limits of accuracy, especially for the lead. The threads in the nut are then cast to each individual screw, the threads and the backing forming an annular lining in the bronze shell that forms the outer section of the nut. After the babbitt cools, the threads fit so snugly that it is necessary to apply mechanical power to loosen the nut from the screw. To obtain a free working fit with sufficient clearance for good lubrication, the threads are lapped in oil. The resulting fit shows a uniform effective bearing over the entire working surface of the thread.

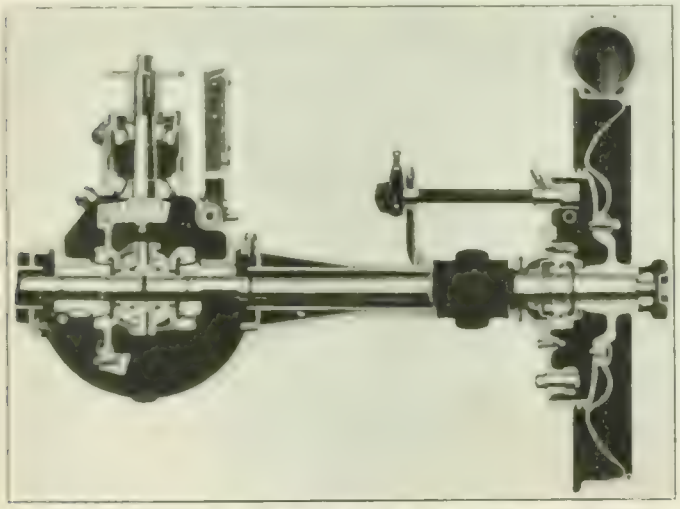


Fig. [illegible]—Front Axle and Brake Construction

The Rear Axle

Economy, as we have seen, implies dependability and durability; for, without securing these in a very large degree, there is necessarily an expenditure of time and money. Dependability and durability in rear-axle construction do not refer only to uninterrupted performance of the axle as a means of transmitting power; that is not sufficient, for the element of taste enters into the consideration. Few things are more irritating than a noisy rear axle and, naturally, the owner does not buy his car but does it pay a noisy axle; the noise develops later. But the owner who continues to drive his car very long after the axle develops noise is not above criticism; for, in most cases, if immediate attention is given, expensive repairs and replacements can be avoided as well as the needless annoyance.

The development of axle noise is a useful warning that something has gone wrong and indicates that one or several conditions prevail such as gears being out of adjustment, worn bearings, a broken or distorted bearing post, Brinelling, foreign substance in the axle, worn gears or some developed structural weakness of the axle. These, of course, are not the only causes for noise in axles and do not include those met in the design and manufacturing processes; they are only the fundamental ones in cases where the noise is due inherently to a change from previously satisfactory conditions. Frequently, axle noise is produced by the use of certain types of tire, by the use of tire chains or by other indirect causes, but, in such cases, the axle is not to blame. If the car is driven with the axle in any abnormal condition, the noise will become worse, to say the least, and it is necessary eventually to visit the service-station; but generally something more serious happens, a break is almost inevitable and breaks happen frequently at the most inopportune times and are expensive. However, having recognized the causes of the development of axle noise, it is the engineer's work to eliminate them if possible; or, if not possible, to reduce their effect.

Of the various causes for the development of noise or the subsequent more serious troubles, the change in gear adjustment due to the wear or the failure of the bearings is perhaps the most frequent. In spiral-bevel-gear sets, a spiral angle of about 30 deg. is used generally. The pinion axial thrust for angles in this neighborhood approximates 50 per cent of the tangential tooth-load. Hence, the load on the bearing that is reacting against the pinion thrust comprises a radial component and a thrust component of nearly 50 per cent of the radial component; the direction of the resultant load-line is inclined about 60 deg. to the axis of the bearing.

With taper-roller bearings having the small cone angles common to usual designs, the complementary thrust component for a given radial component is much smaller and, therefore, a secondary radial load that acts in addition to the imposed radial load is created. By the use of larger cone angles, the complementary thrust capacity can be made higher in proportion to the radial load capacity to any reasonable degree, the maximum efficiency of design being reached when these component capacities are proportional to the imposed thrust and radial loads.

With the usual cone angles, the amount of axial play developed during wear is several times greater than the amount of radial wear and, therefore, the gear adjustment is affected quickly. The proportion of end-play that is developed with a similar amount of wear of the bearings in which the cone angles are larger, is greatly reduced and thereby maintains the gear adjustment for a much longer period for a given amount of wear. These two advantages of steep cone-angles are especially important in large high-powered cars in which the axle design is necessarily more compact than in lighter cars of less power. Fig. 27 shows the layout of the single-eight axle in which these bearings have been adopted.

In the case of the differential bearings, an increase in the diameter of the outer race results in a lower resistance to distortion from the true circular form. It is important that the circular elements be maintained; as otherwise, secondary stresses will be set-up during the operation of the bearings. For this reason, wherever possible, it is a great advantage if the strength of the bearing races are aided by their mountings in resisting the deformations caused by the imposed loads.

Where the differential bearings become large, as in the case of axles for cars of the single-eight weight and power, the usual construction of split differential mountings in which the outer race of the bearings is clamped under a cap possesses the fundamental disadvantage of a lack of rigidity. In the first place, very great care

must be exercised in the machining operations to insure an almost perfect fit between the race diameter and the bore into which it is to fit. This is initially difficult, as the cap is bolted in place in the differential carrier and the bore is ground while the cap is under an entirely different system of stresses than those for the condition in which the bearing is clamped in place. After the grinding operation is finished and the bearing mounted in place and clamped, the circular form of the bore is no longer maintained. The result of this is that the bearing is subjected in operation to localized stresses wherever the diameter is the smallest, although there is a tendency for an elastic adjustment to take place in the bearing.

Generally these localized stresses are very much higher than the normal stresses for which a better distribution of the loading of the rollers and the races is found. Bearings operating under these abnormal conditions show two characteristic types of failure; the races become badly pitted in the areas of stress localization, or the race cracks completely. Frequently, however, rollers show failure; but, in this case, it is difficult to determine whether the failure is caused by race distortion or because of improper adjustment, unless the races themselves show distress. To add to the distortion caused in the original clamping of the bearings, the cap itself is subjected to a stress distribution that is not favorable to the maintenance of a circular form under the applied bearing loads.

To eliminate these fundamental disadvantages in the mounting of large bearings, we have adopted the construction as shown in Fig. 27, which is a mounting and type just the reverse of the clamp mounting. In this construction, the outer race of the bearing is pressed into the solid circular annulus of the differential case. With this construction, the circular form of the outer race is maintained accurately. The form of the inner race is also maintained in this mounting. The inner race is pressed-on to the end of a carefully ground cylindrical sleeve. This sleeve is stepped in two diameters, the larger of which is relatively long and fits a closely reamed seat in the differential carrier. The outer end of the sleeves is threaded for adjustment. Such a mounting eliminates the formation of any secondary stresses and thus allows the bearing to do its work most efficiently and have the longest life.

Conclusion

I have pointed out that the basis of motor-car transportation comprises the elements of performance, safety, economy, comfort and taste. To these every thought and effort devoted to the engineering and production of the modern automobile will find a definite causal relation. We strived for a certain degree of performance in coordination with the other elements and achieved that which we set out to do. We determined on a degree of safety for large cars that we felt, in addition to the standard of inbuilt safety that we have always tried to maintain and the improvement in steering control which we accomplished, required a brake on each road wheel. The simplicity and accessibility of the engine, along with the improvements that are constantly being effected in the advance of craftsmanship in engine building; the improvement in the transmission and rear-axle design; and the improvement in many minor details have, we feel, established a new standard in economy above that reached by our previous efforts on cars of this class. Comfort and taste have, we feel, been satisfied in a larger measure. Approval of the inherent smoothness of the single-eight, to say nothing of that relating to the appearance, the quality and the texture of the upholstery and the many other appeals that have been a constant object of our efforts for years, we leave to the user's own judgment.

THE PRODUCTION AND USE OF SILVER

SILVER is produced largely as a by-product, since the ores of which silver is a derivative are mined primarily for other metal content, gold, copper, lead and zinc. Reputable estimates state that silver production comes 70 per cent from base metal ores; 30 per cent from precious metal ores. The amount of silver found is of secondary consideration. Therefore, the world's supply of the white metal is involved with many cross currents of the supply and demand for other things.

According to figures prepared by the Director of the Mint, the annual silver production of the world was running about 225,000,000 oz. in 1913, just before the war began. Since then it has not reached as much as 200,000,000; the low point was touched with a production of only 161,000,000 oz. However, a production of 198,000,000 was reached in 1918 when the war demanded large supplies of metals generally. The figures show that as a rule the North American Continent contributes about three-quarters of the annual world production; the United States usually rather more than one-third. Mexico, before the revolution, ranked first as a silver mining country. But for a long time thereafter production was but a fraction of that of former years. Indeed, the curtailment of world supply from 1914 through 1921 can be largely traced to the Mexican revolution. Given a continued stable political condition in Mexico, it is thought that production there may hold the pre-revolution stride which it picked up again in 1922. Last year the 81,000,000 oz. produced broke production records for recent years. Some of the Mexican mines have been operated for hundreds of years, but experts think that silver deposits show no signs as yet of exhaustion.

After Mexico in silver production comes the United States; indeed, during many of the revolutionary years the United States was ahead of Mexico. The third place belongs to Canada; the remaining quarter of the world's annual production is divided among the other continents.

North America produces the surplus of silver; India and China absorb it. This generalization appears to be fairly well substantiated in experience. When the affairs of the world were flowing along relatively evenly in the years just before the war, there was a rough equation between the exports of silver from the United States and the imports of silver into India and China. During the years 1910 to 1914, the United States annually exported about 100,000,000 oz.; the annual net import of China and India was about 90,000,000 oz. It is perhaps fair to consider the exports of the United States as representing the surplus product of North America, as most of the exports of silver of Mexico and Canada leave North America through the ports of New York and San Francisco. With North America balanced against the Orient, the silver produced by the rest of the world supplies the demand for silver in the rest of the world, roughly speaking.

The war created a tremendous demand for the products of India, cotton, jute, rice, wheat. And at the same time it cut down the return flow of imports from the rest of the world, piece goods, iron and steel. To strike a balance of trade with India, the precious metals were much in demand. The gold of the world found a particular magnet in the United States; India was the magnet for silver. Hand-to-hand coins, note reserves, personal ornaments, individual hoardings in India have always been chiefly silver. In the war years the silver that the rest of the world paid for Indian exports was largely buried in that land where every man is his own banker.—*Commerce Monthly.*

Engineering Brains in Fleet Operation

By [illegible]

Metropolitan Section Paper

The organization of the business of the American [illegible] Express Co. requires that careful consideration be given to the details necessary for economical operation. The equipment comprises 12,755 vehicles, of which approximately one-third are motor driven and have a carrying-capacity of more than one-half the total. On July 1, 1918, when all the express companies were merged into one organization, it was found that the motor-vehicle equipment included 59 different makes and 131 different models. Among the 377 trucks built by one company were 21 different models. Diversity of equipment, of course, complicates the maintenance problem and adds to the cost. Additional expense is incurred frequently by purchasing and experimenting with parts offered by makers of accessories such as carbureters, spark-plugs, wheels and the like. Careful inspection, adequate lubrication and the adoption of "stitch-in-time" methods will save needless expense.

Exclusive of drivers' wages, depreciation, interest and insurance, the operating costs are shown to be distributed according to the following percentages: Gasoline, 9.00; cylinder oil, 2.25; tire costs, 2.50; painting, [illegible]; body repairs, 4.75; chassis repairs, 35.20; and garage expenses, 24.00 per cent. In the eight largest cities of the Country, 6254 calls for assistance were received at the garages during the year; of these, spark-plug troubles comprised 5.9 per cent; ignition system, 9.1; carbureter, 8.6; gasoline lines clogged, 7.6; broken fans or fan-belts, 9.3; and steering-gears, clutches, transmissions, drive chains and tires about 3 per cent each. In the same cities, the calls for garage service by 722 electric trucks were less than two per truck per year. Exhausted batteries caused 19.1 per cent of the trouble; controllers, 12.1; steering-gear, 6.2; brakes, 5.0; drive chains, 11.6; field or armature burned out, 4.8; and springs, 1.3 per cent.

THE business of the American Railway Express Co. is transportation. In fact, transportation is its sole function. Sight is sometimes lost of the fact that high efficiency in the business of transportation can be attained only through a most careful analysis and a careful consideration of the fundamental problems that necessarily must be solved to assure perfect and economical operation for the longest period of time. Transportation in the case of an express company must be reduced to a science. No sentimental selection of equipment, guesswork method of operation or slipshod method of maintenance can be tolerated. During the year 1922, more than 184,000,000 shipments were handled, and these shipments had to be handled at least once at the point of origin and at least once at the point of destination, in addition to handlings on the way. The average weight per shipment was approximately 82 lb., producing a gross revenue of approximately $294,000,000. From the magnitude of the business it can be seen readily that it is necessary to make a most careful selection of vehicle equipment.

In New York City, we require 655 motor and approximately 900 horse-drawn vehicles. In Chicago, we have in daily service about 648 horse-drawn and 306 power vehicles, including 25 tractors with about 60 trailers. Our total vehicle equipment throughout the United States and Canada consists of 2636 gasoline-driven vehicles, 1195 electric street-trucks, 324 electric industrial platform-trucks and 100 semi-trailers and about 8500 horse-drawn vehicles. This is a total of 12,755 units of which approximately 33 1/3 per cent are motor vehicles; but the 33 1/3 per cent of motor vehicles, to the best of my knowledge, has a carrying capacity of more than 50 per cent of the total. Statistics show that, in our service, the horse-drawn vehicle averages approximately 12 miles per day, the electric vehicle 20 miles per day and the gasoline vehicle 30 miles per day, which surely is sufficient to prove that, if we could get a record of ton-miles, the motor vehicles are doing by far the greatest amount of actual work.

In the beginning, from 1912 to about 1917, the experiment was in the making and there was need of engineering brains in the maintenance end, because the changes were so rapid that only alert quick-thinking maintenance men could hold the pace set by the engineers. It is a lamentable fact that on July 1, 1918, when all the express companies were merged into one, the new organization found itself in control of 59 different makes of motor vehicle and 131 different models. There was a large number of old-line, or so-called manufactured, trucks. One would think that if we had purchased only one make we should have had a standardized maintenance proposition but, out of 377 trucks built by one old-line company, we had 21 different models in which the parts were interchangeable only in a small degree, and one can see how far from standardization we were kept by the engineers. In the trucks recently bought from an old-line company, changes were made without notice to us, after we had received the first lot and before we received the second lot, even though the second lot was purchased within a few months after the first, so that it was necessary for us to carry two types of radiator in the stockroom when one should have been enough. In one particular case, in a fleet of eight trucks received from an old-line company, all delivered at the same time, there were three different makes of magneto. This great difference in models and in constructional units complicates our maintenance problem and adds much to its cost. We realized, though, in the beginning, that we were starting with an industry in which there would be rapid development and, while we were saddened by the cost of maintenance, we are gladdened by the fact that the developing of motor trucks and the standardizing of parts has, we believe, reached a stage of common practice. In selecting equipment, our engineering knowledge teaches us that the words "manufactured" and "assembled" are dissolved into one word and that a so-called manufactured truck and a so-called assembled truck in which the important constructional units have been designed properly and properly assembled will be found to be identical, and that with either truck maintenance should be performed economically and the satisfactory performance of the truck be assured.

The selecting of motor-vehicle equipment certainly has much to do with the maintenance problem, and here again engineering knowledge is necessary to keep away from

[illegible] manager of motor-vehicle equipment, [illegible] New York City.

complicated apparatus or apparatus that is vastly different from standard or common practice. The fleet-owner or the buyer of motor trucks should not complain or criticize engineers for what has gone before. It was necessary to study, work out and improve the designs, but though engineers are able to produce a motor vehicle that will perform satisfactorily and economically, there is still need of engineering brains to avoid the expense of hundreds of accessories offered by others than the truck builders. We receive trucks equipped with carbureters that were worked-out by engineers, yet hundreds of carbureters are changed daily because the owners or the buyers have been influenced by sales talk. I do not know how many spark-plugs there are to be had, but I do know that there is only a slight difference, if any, in their intrinsic value, and that the owner or the operator who is continually trying different spark-plugs is creating an unwarranted expense.

Necessity for Engineering Knowledge

I believe it is unnecessary to have an engineering staff to supervise the actual maintenance and repairs, but I believe it is necessary to have engineering knowledge to keep the mechanical forces or inexperienced executives from substituting or changing from one thing to another that will prove no better. Take, for instance, the subject of wheels. The old wood artillery-type wheel has given comparatively little trouble; the solid steel wheel may be just as good; in fact, I think it is, and I believe there is a real benefit to be derived from the use of the so-called resilient wheel under certain conditions, but truck owners should not be influenced to the extent of incurring an expense for any accessory unless they have sufficient indisputable knowledge that the expense will be returned by economical performance or extended life. Therefore, before changing from the conventional type of wheel or the conventional type of tire and adopting some of the so-called resilient wheels or semi-pneumatic tires, a careful analysis should be made by a competent engineer whose unbiased mind should enable him to advise what is best.

In the old days, the frames were a continual source of trouble but, under the practice of today, it takes something out of the ordinary to break them. We do not have broken frames to contend with in regular service, but we should have them if we did not exercise proper supervision over operation and, by inspection and stitch-in-time methods, keep the rivets tight, the wearing parts properly lubricated and the natural wear corrected. The same thing applies generally to most of the other principal units of the truck; that is, to the steering, transmission and axle units, which should be lubricated and adjusted to compensate for the natural wear. There is hardly any reason for neglect, other than gross carelessness, when matters need attention on units that afford easy access for inspection and repair. Occasionally, faults develop in the hidden mechanism of the engine and, due to poor judgment, they are not given attention in time to prevent expensive repairs. The engine is deserving of and should have careful inspection by competent repairmen so that it may have a fair opportunity to operate satisfactorily with the other units of a well-designed and well-built motor truck for a reasonable period, until general repair or rebuilding becomes necessary. We know that much has been accomplished by engineers in the way of simplification and standardization and we should like to see them continue, were it not for the fact that carrying standardization too far in motor vehicles would deprive them of individuality. To my mind, building motor vehicles has reached the stage of common practice, but the engineers must engineer some individuality into the cars.

TABLE 1—OPERATING-COST DISTRIBUTION

Item	Per Cent
Gasoline	30.00
Cylinder Oil	2.25
Tire Costs	2.50
Painting	1.30
Body Repairs	4.75
Chassis Repairs	35.20
Garage Expenses	24.00
Total	100.00

I have asked engineers to develop a mileage-counter, but there seems to be great indifference on the part of truck engineers, who have let the old hub-odometers remain. This instrument probably would record regularly and accurately were it not for the fact that it is placed in the most hazardous position possible. The difficulty with it is that it will not withstand the abuse of collisions with curbstones and elevated railroad pillars and with other hubs. It is impossible for the truck owner to keep records based on actual miles traveled, because no hub-odometer will withstand such usage. Also, I have asked engineers to provide a standardized radiator-guard or at least to complete the work when they turn it out by applying a radiator-guard. In many cases, they leave this to the owner. I have tried repeatedly to find out why it is necessary to remove the seat cushion in a motor truck, almost without exception, to fill the gasoline tank. Why can we not have a filler-pipe extending through the seat panel so that the tank can be filled without disturbing the seat cushions and the cab curtains?

Distribution of Maintenance Costs

The figures in Table 1 will be interesting to those who have not gone into operating-cost distribution in detail; the figures do not include drivers' wages, depreciation, interest and insurance.

Gasoline is one of the most important items of expense, and a live garage superintendent will always watch that item. For some reason, gasoline seems to be the common prey of everybody. It is more likely to be used indiscriminately than any other item. Employees use it for washing parts, and employees and officials of the firm using their own cars for the company's business feel that they should have their gasoline tanks filled; but all these things can be and no doubt are controlled. Gasoline should be saved, first, by knowing that the carbureter is right for a particular truck, and that if any adjustments are to be made they should be made by a capable carbureter man. Better still, a non-adjustable carbureter should be used, if possible. The drivers should be taught that a rich mixture, which may get them over the grades without shifting the gears, is bound to waste 35 per cent; this waste will accumulate carbon which, within a short time, will cause the engine to work badly. As a matter of fact, if a driver would shift the gears, he could go over the grade with the machine in better condition than a person can who believes and relies upon the wonderful flexibility or pulling power of his particular truck or passenger car. Numerous gasoline savers or adulterants are offered for sale. The vendors claim to eliminate carbon and to crack or break-up the gasoline in such a manner that much greater mileage will result. I have tried a number of these gasoline adulterants without any benefit, and I believe that the Society will bear me out in the statement that, from

TABLE 2—DISTRIBUTION OF CHASSIS OVERHAUL COSTS

	Labor Time		Labor Cost		Material Cost		Overhead Cost	
	Total, Hr.	Per Cent	Total	Per Cent	Total	Per Cent	Total	Per Cent
[illegible]	27 45	3 67	$50 57	4	$6 81	0 17	$51 41	3 65
[illegible]	196 45	26 23	135 81	11 18	26 85	6 71	351 69	30 33
[illegible]	8 00	1 07	8 00	1	0 00	0 00	8 00	0 64
[illegible]	5 00	0 65	4 17	0 34	2 13	0 53	6 60	0 47
[illegible]	25 00	3 39	17 00	1 41	0 75	0 08	12 56	0 83
[illegible]	17 00	2 27	11 00	0 91	11 44	2 91	21 74	1 54
[illegible]	8 00	1 07	7 00	0 58	51 08	7 78	89 71	6 35
[illegible]	10 00	1 33	7 00	0 58	2 80	46 22	6 51	66 50	4 72
[illegible]	3 00	0 40	3 00	0 25	0 50			3 52	0 25
[illegible]	42 58	5 68	62 14	5 16	5 91	1 41	0 16	68 55	4 51
[illegible]									
[illegible]	31 85	4 41	25 41	2 11	5 03	44 27	6 25	69 69	4 94
[illegible]	41 50	5 71	28 37	2 14	1 78	0 75	43 85	3 18
[illegible]	63 85	4 79	38 15	3 15	28 85	1 07	61 96	4 61
[illegible]	7 85	1 08	8 14	1 16	5 75	0 84	14 09	1 00
[illegible]	18 40	2 61	19 25	2 71	15 17	2 11	31 40	2 14
[illegible]					5 68	0 79	5 68	0 40
[illegible]	16 50	20 76	100 18	28 59	0 25	0 13	201 43	14 29
[illegible]	5 50	0 76	5 58	0 80	90 50	12 76	96 08	6 81
[illegible] Total	727 28	100 00	$701 09	100 00	$708 81	100 00	$1 409 90	100 00

This was a little less than seven times per truck per year. An analysis of the causes of these calls, stated in percentages of the total number, is made in Table 3.

There were only 50 cases of bearing-trouble, and rarely a case in which a full set of connecting-rod bearings burned out. The spark-plug trouble in Table 3 was due, almost without exception, to the fact that the driver had been using a choker and had fouled the plugs by too rich a mixture; this gave us an opportunity to teach him that the trouble could have been avoided if he had used the gearset. During the same period and for the same number of trucks the spark-plug replacements on four-cylinder engines have been a little less than six per truck per year, or a little less than one-half of one spark-plug per truck per month. The ignition system parts other than the spark-plugs, such as the magneto, the distributor, the wiring and the switches, that caused the trouble stated in Table 3, required only slight adjustment or repair as a rule, because the trouble was of minor importance. This work was done at once and the truck was able to resume its work immediately. The miscellaneous troubles in Table 3 were minor, such as

TABLE 3—ANALYSIS OF CAUSES OF TROUBLE CALLS

Cause of Call	Per Cent
Engine Bearings	0.8
Spark-Plugs	5.9
Ignition System	9.1
Carbureter	8.6
Gasoline Lines Clogged or Leaking	7.6
Broken Fans or Fan-Belts	9.3
Radiators	1.1
Water Pump or Water Line	1.6
Radiators or Pumps Frozen	0.2
Governors	0.5
Steering-Gears	3.3
Clutch	3.0
Propeller-Shaft	1.5
Universal-Joints	1.1
Transmissions	3.0
Differentials	0.5
Rear Axles	0.9
Radius-Rods	0.9
Drive Chains	3.8
Wheels	1.5
Springs	1.8
Brakes	2.2
Tires	3.3
Lights	1.0
Accidents, only	1.6
Out of Gasoline or Oil	3.1
Miscellaneous	23.8
Total	100.0

the economy of using gasoline-cooled gasoline-saver of the water-jacket crystal or tablet type are not valuable. I believe that auxiliary air devices that are operated from the dash so the driver may use it will accomplish nothing, but there is a possibility that an auxiliary air device may be constructed so that it will function only at pre-arranged engine speeds, by working it up with an accumulator tank or with a fly-ball governor. Then again, this means only a lean mixture and so go back to what I have said before. If you can teach the driver to use the gearset installed by the maker of the vehicle, at least 35 per cent of the gasoline now used can be saved.

Nothing connected with the maintenance of motor vehicles can be more confusing to the lay mind than the question of cylinder oil suitable for lubricating engines. I believe that oil refiners are serving the Country with the best that can be obtained from crude petroleum, but the owner or the buyer generally knows little about oil and must make a selection from hundreds of samples.

The next item of expense is tire cost, which we must agree is very low. As a matter of fact, tire cost today is approximately 25 per cent of what it was in 1913 and 1914. Solid and pneumatic tires are showing at least four times the mileage they did in the period mentioned, and they are giving from two and one-half to three times as much service as the old mileage guarantee, which was from 3500 to 5000 miles on pneumatic tires and from 7000 to 8000 miles on solid tires. The percentage of replacements for defective workmanship or material is so low that it is of practically no importance.

The prices of painting, of course, will differ, but, generally, to keep trucks well painted the cost should not exceed that which I have mentioned.

Bodies with durability built into them in the beginning should not cost more than the amount given for repairs, and I believe they should last fully as long as any chassis upon which they have been installed.

The greatest item of expense is mechanical repairs to the chassis. That surely should not exceed the amount I have mentioned, and here again I fully believe the cost can be kept down only by taking a stitch in time; by lubrication, which it is criminal to neglect; and last, but by no means least, by instructions worked out to give the driver a more extended conception of his duties and of his responsibility for the valuable equipment placed in his hands. The distribution of chassis-overhauling costs is stated in Table 2.

Garage expenses can be controlled because, generally, they are fixed, with the exception of light and heat. As a matter of fact, light and heat are controlled by the [illegible] to a great extent.

Analysis of Emergency Calls

For the year 1922, I have taken the cities of Atlanta, Buffalo, Chicago, Cleveland, Detroit, New York, San Francisco and Washington. In these cities you have the great cold cities that have little snow, and cities that have no snow and no cold weather. In these cities there are 502 gasoline trucks, very few being of less than 2-ton capacity, the greatest number being 2 and 3½-ton capacity and a considerable number being of 5-ton capacity. Generally, there are 300 working days per year, but, [illegible] trucks, we have obtained 306,348 working days of 8 hr. each. The total mileage, as near as we know, was 9,730,450 miles.

During the year we received 6254 calls for help from [illegible] something was the matter with the truck, and the driver called for assistance from the garage

the inability of the driver to start the engine, or on account of the stalling of a truck in a ditch or in the mud or snow.

During 1922 and in the same cities, we had 722 electric trucks; from these we obtained 226,716 working days. We were called out less than twice per truck per year on account of these trucks, for a total of 4,987,752 miles. During the year we had approximately 91 electric motors burned out; that is, either the field or the armature burned out. This was 4.8 per cent of the trouble, but it is small when the total mileage is considered. In many cases it was due directly to the fact that the trucks encountered deep snow, mud, ice, cold, rain, heat and, in all probability, considerable overloading. We had 366 cases of exhausted batteries, which caused 19.1 per cent of the trouble, or an equivalent of one case of trouble per truck in 2 years. The other items of importance were controllers, which caused 12.1 per cent; steering-gear, 6.2 per cent; axles, 1.5 per cent; brakes, 5 per cent; springs, 1.3 per cent; and drive chains, 11.6 per cent. On the modern electric truck drive-chain troubles have been eliminated. The remainder is made up of miscellaneous items too numerous to mention, but those who are doubtful of the ability of the electric truck to perform should take note of the fact that 722 electric trucks performed better than 314 truck-days per year, with less than two trouble calls per truck per year. Surely, all of the above is an indication of the reliability of the motor vehicle and its component parts and an indication of the service that can be accomplished under proper management.

The business spotlight is being turned on the motor truck and the organization back of it. The light should be focused first on the organization of maintenance; second, on the organization of operation. Each organization should be required to analyze costs and to study legislation referring to truck operation. Each organization should be required to analyze costs in order that nothing shall be left undone that will bring about greater efficiency and satisfaction to the owner.

THE DISCUSSION

J. F. WINCHESTER:—Engineering brains have conceived the motor truck, have placed it in its present position of reliability and are about to create for it a more varied and a wider field. Some standardized form of cost analysis is needed, so that one operator can compare the results he is obtaining with those obtained by another. Although, in the past, we have had certain standardized forms of bookkeeping to accomplish this, my observation is that they are complicated and tend to result in confusion when direct comparisons are made. Therefore, I suggest that careful consideration be given to the basis on which a cost analysis should be made.

The unit of cost will vary in different industries but, when a direct comparison of the costs of mechanical operation is to be made, should this be by the individual truck from the date of installation, by fleet operation, that is, an average by make and model, or by year; and to what degree or extent of detail should these figures be carried out? Simplicity should be the guide in deciding this question, for there is no doubt that there is a great tendency to analyze the various operating costs in too great detail, which results finally in confusion to a prospective user.

My reason for suggesting a standardized form of bookkeeping is that, in some particulars, the results of my experience do not conform to those of Mr. La Schum and of other authors. Mr. La Schum states that the light should be focused first on maintenance and second on operation. My experience has been, even though I am a mechanical man first, that this order should be reversed. The reason is that the organization of operation controls the items of expense that develop fixed charges, which constitute approximately 65.2 per cent of the total operating charge, while the organization of maintenance controls the group of charges that make up the variable costs, which are largely mechanical expenses, and which my analysis shows constitute approximately 34.8 per cent of the total. My division of fixed and variable charges is approximately as stated in Table 4.

TABLE 4 DIVISION OF FIXED AND VARIABLE CHARGES

	Items	Per Cent	Per Cent
Fixed	Salaries, Chauffeur and Helper	43.4	65.2
	Storage and Insurance	2.0	
	License	1.0	
	Depreciation	18.8	
Variable	Gasoline	11.3	34.8
	Lubricating Oil and Grease	0.8	
	Tires	9.9	
	Road and Miscellaneous Expense	10.4	

In considering unit costs, whether they be costs per ton-mile, per package or per some other unit of value, it is a fact that careful planning, routing and proper equipment in connection with the installation will be the greatest factors in keeping costs down. The variable charges, although constituting 34.8 per cent of the total, include such items as gasoline, lubricating oil and grease, which, provided the equipment is operated efficiently, are difficult to offset. We know that the efficiency of a truck depends to a large extent on individual mechanical design and on materials and that no great economies can be obtained in similar models, provided the truck is watched carefully from an inspection standpoint. I submit, therefore, that the responsibility of the organization of maintenance is secondary to the organization of operation, and that it should render to the organization of operation efficient service from an engineering and a general operating standpoint so that unit costs can be kept down to the minimum figure. Friction between the two organizations should be avoided and harmony should be maintained. Either should be able to pass on the figures of operation, so that constructive criticism can be obtained from both units of the organization.

COMBINED ENGINEERING AND BUSINESS ABILITY

The question as to whether engineering brains should direct the operating of a truck fleet will always be debatable. In supervising either kind of expenditure shown in Table 4, I believe that a business man, no matter how keen he may be, works under a handicap unless he has had some engineering training. The wider his engineering training is, the better position he will be in to discuss and to pass on the many problems that arise.

The points brought out in Mr. La Schum's paper that illustrate problems in connection with carbureters, sparkplugs, tires, wheels, frames, gasoline savers, auxiliary air-devices and the like indicate that engineering knowledge is necessary if these types of accessory are to be passed upon individually, without expensive experimental work. Repair and maintenance work are primarily

mechanical and if the management is to be efficient and economies are to be created, the person in charge should be able to judge whether the recommendations made to him are right or wrong from an engineering standpoint. The point to be avoided in any operation is the duplication of experimental engineering work previously conducted by a factory organization, by the Society or by others, the results of which are accessible. I have failed to encounter some of the problems cited by Mr. La Schum. For instance, in the last 2 or 3 years, there have been installed under my supervision approximately 500 trucks, having uniformity in their specifications covering speedometers, magnetos, lighting equipment and accessories, such as batteries, switches, headlamps, tail lamps and so on, which tend to simplify the service problem and keep down the cost of maintenance after the vehicle is in operation. No difficulty of any importance was encountered with the builders in getting them to use standard accessories.

I have found no difficulty in recording mileage. All mileage reports in the records to which I have access and from the vehicles under my supervision are based on speedometer readings; I believe that at least 98 per cent of the mileage turned in is based on the accurate results obtained from these instruments. A few years ago satisfactory speedometers and driving mechanism were difficult to obtain, but the difficulty was caused by driving the speedometer from the front wheel; that is a bad location, as the instrument is exposed to the elements, and results in the rapid wearing out of the universal-joints and the gears. By developing a drive taken from the rear of the gearbox, this trouble practically has been eliminated. It is also my belief that, within the last several years, front-wheel speedometer-drives have been developed to the point where little difficulty is being encountered, comparatively speaking. By fastening the parts in such a way that the effects of vibration are overcome, the upkeep of this type of drive has been reduced to a minimum.

Attention has been called to the mechanical changes in various models of truck bought from an old-line company. A suggestion that I offer to the Society contemplates the working-up of a mechanical-installation sheet along standardized lines that would give complete mechanical specifications to the truck operator concerning the type of installation he is to make. The sheets, if prepared carefully by the builder of the truck, would record the changes made in its construction and would assist the fleet operator materially in ordering material for a given truck. The sheets should be designed so that they will allow the fleet operator to record standard changes, such as boring oversized cylinders, gear-ratio changes and the like, which sometimes are necessary after a truck has been installed and which, to give satisfactory service in the field, are necessary for the maintenance organization to have ready at all times.

Standard catalogs, as supplied with cars in the past, do not take care of this problem satisfactorily. If fleets are to be handled more economically in the future, it is necessary to have detailed information rather than the general information contained in "parts" catalogs.

Another suggestion is the need of greater speed on the part of the truck industry in supplying fleet operators with complete engineering data regarding a given vehicle, so that a company operating a particular type of equipment can have definite engineering recommendations regarding clearance of fits in installing various parts, such as pistons, bearings and the like, then, when overhauling work is being done, there will be a definite assurance that the unit will operate satisfactorily when put together. This, together with a basis for fleet-repair rates, is to my mind a great need in the truck industry if fleets are to be operated economically. Many of the larger operators are able to solve these problems themselves because they produce economical operation; but, in the case of the smaller fleet-operator, this work constitutes an expense that is difficult for him to absorb and hardly justifies his going into.

Fleet Operation Costs

I have never been able to pass-up the subject of tire cost from the standpoint of tire cost only. My experience proves that the type of tire employed has a definite relation to the efficient operation of the truck itself. We in the automotive industry have heard certain claims made by tire manufacturers for different types of solid, pneumatic and cushion tire, and also by wheel manufacturers on the subject of reducing operating cost. We must feel sorry for the operator who paid great attention to the various claims made for pneumatic tires in the last few years for trucks of 3½-ton capacity and over, although I believe that certain types of pneumatic tire can be employed to advantage for lighter equipment. Why should we consider tire cost only, in view of the differences in repair and mechanical-upkeep cost on various types of tire which indicate that a large saving can be made. Table 5 is illustrative of this point.

Based on the difference in cost stated in Table 5 and assuming that 100 trucks ran 25 days per month, 12 months per year and 35 miles per day, we have a total of 1,050,000 miles per year. The difference in the mechanical-repair cost in this case represents a saving of $32,970 per year, while the difference in the total mechanical cost represents a saving of $46,200 per year. These figures indicate why we should keep tire records and the reason for my contention that we should not arbitrarily consider one type of tire as good as another and figure tires on cost alone.

In connection with standardized fleet-operation cost, I suggest the necessity for a standard form of distribution of chassis-overhaul cost. The figures presented by Mr. La Schum are interesting, but it is difficult to make comparisons from the information submitted because the factors on which the costs are based are not stated clearly. Do his cost figures represent the cost of overhauling a 2, 3 or 5-ton vehicle, or do they represent an average of a number of vehicles? What mileage had the vehicle traveled before the overhauling was done? How old are the vehicles? How long did the vehicle operate after overhauling as compared with when it was new? These are questions that come to my mind in connection with the cost. My experience on one item in this classification leads me to believe that a 5-ton motor-truck, after traveling from 18,000 to 24,000 miles, should be overhauled on a labor-hour classification on an

TABLE 5—DIFFERENCES IN MAINTENANCE COSTS

		First Type	Second Type	Differences
Duration of Operation, Months		27	25	.....
Total Maintenance Cost per Mile	Tires	$0 0273	$0 0167	$0 0106
	Repairs	0 1043	0 0729	0 0314
	Mechanical	0 1759	0 1317	0 0442

average of not over 90 hr., while the total repair-cost, including all charges, should not exceed an average of $900.

Maintenance Difficulties

The analysis of troubles shown by Mr. La Schum is very interesting. I believe the results of analyzing any particular fleet of trucks would depend largely on the types of vehicle employed. The type of vehicle, the road conditions and the average age of the fleet will make a great difference in the percentages. Disregarding these particular points, however, I seldom see or hear of trouble on the following items: Spark-plugs, carbureters, gasoline lines clogged or leaky, governors, propeller-shafts, universal-joints, radius-rods, drive chains, wheels, brakes out of order, gasoline and oil shortage or tires. Systematic inspection, strict attention to the education of the operator and methodical operation have eliminated the majority of the above complaints. Using a strainer funnel of the proper design, or a proper filter in the pump or in the nozzle of the hose from the pump, usually will prevent gasoline lines from becoming clogged or leaky. Instructing the driver in the use of spare chain links will take care of broken chains. Governors usually give trouble by failing to govern, but we never hear of an operator who is dissatisfied from this standpoint. Operators should be trained to detect spark-plug trouble; I seldom have trouble of this nature. My spark-plug consumption has been approximately one spark-plug per cylinder per year and the individual design of the oiling-system, and the skill of the operator play an important part in this. One type of car that we operate continuously has trouble with the forward cylinder. It is difficult to detect when this trouble is about to appear and, because of this difficulty, the spark-plug consumption on this particular design of car tends to make the fuel consumption higher than it would be ordinarily.

One of the greatest items of expense to the average operator is due to having vehicles out of service. Particular stress should be laid on this point and accurate records kept of the average time a vehicle is in operation. I believe that any cost system that fails to recognize this important fundamental will not give accurate results. Based on my experience, I believe that a fleet operating over an extended area and not coming into a central garage each night, a fleet that is left largely in the hands of an individual operator, except for a bi-weekly inspection, can be operated efficiently with a reserve equipment of approximately one truck for each sixteen trucks in service. If an operator has his vehicles under efficient central control and has a systematic method of upkeep, this reserve equipment could be reduced still further.

Future Practice

Although the vehicles in the industry are becoming more standardized from a standpoint of general construction, there are still many details and many practices that can be worked out to clear up some misconceptions that still exist. Continued tests of various grades of fuel should be made such as were made recently by the Society in cooperation with other organizations. Closer study should be made of the lubrication system by engineers, as there is a very wide variation in the lubricating-oil consumption per mile in different types of design. Magazine articles and instructions come to me having to do with the changing of lubricating oil at definite periods. The general figure mentioned by various companies is approximately from 500 to 600 miles. In checking-up these recommendations, it has been found that the amount of oil in the base of the crankcase exceeded, in some instances, that in others by at least 200 per cent. Provided that all other conditions are equal, the design having the 200 per cent excess of oil should not have the oil changed as often as is desirable for the model carrying the smaller amount. I hesitate to say so, but, based on my experience, I believe a certain magneto that was manufactured in 1914 was more efficient than the majority of the magnetos we have today.

Because of the type of work the vehicles that I supervise do, electric lights are employed for lighting purposes almost exclusively. There is need of paying more attention to the details of the wiring system, to the design of a generator suitable for charging a battery of the nickel-iron type; to a suitable mounting and a mechanical clutch that will permit the disconnecting of the generator when it is not operating. The electric generator should be built so that it will withstand the vibration of motor-truck operation.

There is need for an extensive study of semi-pneumatic or cushion-type tires, from the standpoint of carrying capacity. A suitable definition should be given as to what a semi-cushion type of tire is; and a definite and logical table as to the relative amount of damage done to the highways should be worked-out, so that State officials would differentiate, from a licensing standpoint, between the solid, the pneumatic and the semi-pneumatic tires. Then operators would pay in direct proportion to the damage caused by various types of equipment on varying models of tire.

The influence of the Society should be put behind the elimination of engine or unit numbers of any character, so that the fleet operator who desires to make repairs by the unit system can do so without running foul of the present laws. Invariably, business or passenger cars are licensed according to the engine number and trucks according to the chassis number but, in registering either type, the engine is always considered. Why will not the chassis number alone satisfy both the builder and the State authorities? The present system of making it a felony to change an engine number certainly complicates the prompt overhaul of trucks or vehicles on a unit-system basis.

F. C. Horner:—Several points in Mr. La Schum's paper are of great importance to successful motor-truck operation and should be considered thoroughly at every opportunity. First, what is the best way in which to decide what vehicles to standardize on? Mr. La Schum's experience is a splendid example of the problem of changing over a large number of miscellaneous motor-trucks, more or less nondescript in character, make, model and size, into a scientifically coordinated fleet in which standardization has been the main objective. The explanation of the conditions he describes was the merger of all the express companies into one, but little thought apparently had been given previously to standardization by the individual companies. It appears that, either through ignorance or from the unsatisfactory results with equipment already in use, it had been the policy of their transportation managers to experiment with every new make and size of vehicle brought out that seemed to be better than the older ones. The advantage Mr. La Schum had over his predecessors was that, through records of performance, he could eliminate the "duds" and gradually boil down his fleet to standards of make, model and size that would furnish the best service for the longest time and with the least interruption. But what plan should the beginner in fleet operation follow

in this matter of selection and standardization? I think it would be helpful to have the light of all the experience available thrown on this important question. Although not feeling competent to do so myself, I should like to have some of our technical men discuss Mr. La Schum's statement regarding "manufactured and assembled" trucks. Is one better than the other, when all things have been considered, or do they just about balance?

Careful Inspection Necessary

Another point in Mr. La Schum's paper is the vital necessity for careful inspection methods in motor-truck operation. The most thorough system of inspection in large fleet operation that I know of is to be found in the London General Omnibus Co. Naturally, when human life is at stake, too much care cannot be taken to avoid accidents but, coupled with the necessity for economical operation, maintenance and repair, inspection becomes equally necessary in this case. The "Driver's Report and Dock Overhaul Sheet" is the basis of their inspection system. It covers a 30-day period and all involuntary stops are registered on the report. In another column "Defects and Remarks on Running" are registered, and in the column, "Repaired By" the mechanic making the repairs signs his initials. The month's record then is on one sheet, which is attached to the vehicle when it goes into "Dock" at the end of every 30 days. The foreman and his staff, by consulting the dock sheet, are able to determine the weak spots at once, if there are any, and to remedy them. Of course, even if the dock sheet showed a clean performance for the vehicle, the dock overhaul would be no less thorough. In addition, the inspectors go over every vehicle at night and make any repairs or adjustments that are necessary. One thing will show the thought given to inspection by this company. The steering-arms and the connections are kept highly polished and are wiped off each night with a rag wet with kerosene so that the inspector shall not fail to detect a flaw or failure in the metal, if one be present. It is the "stitch-in-time" methods that "save nine," as Mr. La Schum so aptly puts it. Unfortunately, too few motor-truck operators realize this important truth.

It is of interest to note that almost every motor-truck operator I met abroad referred to the unsatisfactory mileage recorders of today, and most of the recorders I saw in England were of American design. Why we cannot turn out an accurate, durable recorder is a mystery to me for, without accurate mileage records, the operator cannot keep dependable costs.

Engineering Advice

Another important point is the courteous manner in which Mr. La Schum deals with the engineers who design motor trucks. It has always been my opinion that automotive engineers could do more toward helping themselves as well as the truck operators if they knew more about the problems with which the operator is confronted. If the engineers of the truck companies would consult the experienced operators of motor vehicles and would profit by the knowledge gained, it would be unnecessary for Mr. La Schum to remind the Society of the things that have been left undone by the engineers, for many of which there can be no legitimate excuse. Simplification is an important thing that could be accomplished better by the engineer through close cooperation with the operator and by a thorough knowledge of the daily problem. What engineers must do is to simplify their vehicles, make them better, not easier to get at, to inspect, to repair and to maintain and as nearly fool-proof as it is humanly possible to make them. Take off the frills; in service, essentials are the only things that count. On the other hand, what the operators must learn is that the "stitch-in-time" plan pays, that an ounce of thorough inspection is always worth a full-weight pound of repairs. A motor truck is a piece of fine machinery requiring proper care and attention on account of the varied nature of the conditions under which it functions as a means of transportation. Knowledge is power. Neither the engineer nor the operator can expect to reach a state of perfection without a thorough knowledge of the other's problems and close cooperation is the most effective way to obtain that knowledge.

Regarding the question of fuel consumption, a careful check of miles per gallon, by vehicle, by garage and by district, posted in such a way as to create a desire on the part of the garage superintendents and the drivers to lead the field, is one of the best ways to obtain high gasoline-mileage. Analyze your fuel from time to time to see that it is up to the mark. Chart your fuel-consumption records, study them and see where the leaks are, and, without adding frills to your organization, you will get good results.

On the subject of lubrication, it seems to me that it would be an easy matter for the truck builder to determine exactly what oil is best for the engine on his truck and to send out a formula of this oil with each vehicle. This formula would simply be a chemical analysis, so to speak, of what had been found to be the best oil for a particular engine. No mention of any brand or make of oil is necessary; the operator can check-up on his oil by chemical analysis from time to time, and the oil-supply company must toe the mark or lose the business. I tried this some years ago with good results.

E. E. La Schum:—Mr. Winchester said that he could not reconcile the gasoline costs. I think that this may have come about by the fact that I left out interest, depreciation, drivers' and helpers' wages and the like. I think the reason that gasoline cost runs high in operating express trucks is that these vehicles operate almost entirely in congested traffic, running on change gears, backing-up to and pulling away from shippers' platforms and doing a large amount of engine-running while accomplishing no mileage. One of the most difficult things to determine and to prove is whether a cushion wheel, a pneumatic tire or a semi-pneumatic tire is better than a solid tire, because express trucks run exclusively in cities. I can say without hesitancy that road conditions generally are smooth. We do not get vibration, but the fellow who runs between New York City and Philadelphia at a high rate of speed cannot get speed and not get vibration.

W. P. Kennedy:—In Table 1, why are the body and the chassis-repair costs 40 per cent when the gasoline cost is 30 per cent?

Mr. La Schum:—The truck is doing a great amount of running that brings about wear and tear. The body repairs are more apt to be necessary in congested territories, on account of collisions with wagon poles and with each other, when backing-up in close quarters at railroad depots. If it were not for this item of collisions, the body repairs would not amount to nearly so much.

Mr. Kennedy:—What is the 2-ton electric truck mileage without boosting?

Mr. La Schum:—A 2-ton electric truck in proper condition, with the loads varying as they do in the express service, usually will make about 30 to 35 miles per day on a single battery-charge.

MR. KENNEDY:—Have you made any observation as to variation in the tire-maintenance cost due to the effects of different road impacts?

MR. LA SCHUM:—No.

R. E. PLIMPTON:—Will Mr. La Schum tell us how he determines the period of overhaul on which the costs are based? Does it depend on mileage, or time, or on the judgment of the shop superintendent?

MR. LA SCHUM:—It depends on general judgment, but mileage has more to do with overhaul than anything else; approximately, it is done after each 18,000 miles of travel. The trucks to which the costs given apply were two 3½-ton trucks.

CHAIRMAN W. E. KEMP:—Mr. Horner asked you to define assembled and manufactured trucks more clearly.

MR. LA SCHUM:—I have said that the terms "manufactured" and "assembled" resolved themselves into one word. I cannot understand what the difference is, because all trucks are manufactured. Some builders manufacture one unit and some another. The point that strikes me forcefully is that, if you dismantle a so-called manufactured or a so-called assembled truck, and put it on one table, then dismantle another truck and put it on another table, a layman can pick out parts that are identical such as the wheels, radiators, frames and the like. After the layman has picked out the parts that are identical, if you call in a well posted man he will pick out more parts. An engineer will pick out parts, not identical in shape, but identical in function. After you have finished, it seems to me you will have a manufactured truck.

One thing that engineers could do, if it were consistent with good salesmanship, would be to indicate to the truck user that if a part is broken he does not need to throw up his hands just because there is not a service-station next door. There are many sources of supply that will enable him to obtain that broken part. Service-stations are necessary and truck builders and truck assemblers have done much at great expense to bring about the establishment of proper service-stations but, if I have a broken spring, I do not necessarily think of the truck builder, because I know of many places where I can procure the same kind of spring; if I have a broken magneto part, there are plenty of places in which to get the magneto repaired. Ball and roller bearings are interchangeable in a dozen different kinds of trucks. That is true to a considerable extent of engine and connecting-rod bearings, though not so universally. It is more true with assembled trucks than with so-called manufactured trucks. Still I do not see the difference between so-called manufactured and assembled trucks.

W. R. GRAHAM:—Has Mr. La Schum tried pneumatic tires on electric trucks?

MR. LA SCHUM:—We never use pneumatic tires on electric trucks because they are slow and, because of the continuous torque, it has never been considered necessary to try them.

MR. GRAHAM:—What plan should a beginner in fleet operation follow in the matter of selection and standardization?

MR. LA SCHUM:—It is a fact that all the old express companies, before they were merged into one, did considerable experimenting. No industry has done more to help the motor-truck industry, because the express companies spent their money freely and tried many types of truck, not through ignorance, but to assist in promoting the motor-truck industry. After the motor-truck builders had reached a position where they could stand on their own feet and fight for business, the reason the American Railway Express Co. inherited fifty-nine different makes of trucks and 131 different models was reciprocity. All the builders took advantage of the express company because they shipped everything by express. They continued to use the big stick of reciprocity until 1918, when the Government told the express company that it must get down to a standardized basis and give more economical performance.

The so-called assembled truck simplifies the maintenance problem. So many units are identical that, although the trucks are built by different companies, I can maintain them economically.

A MEMBER:—What does Mr. Winchester consider to be the relative value of grease versus oil for a gearbox or differential lubricant?

MR. WINCHESTER:—I can make no relative comparison because I only use and recommend oil for this purpose.

In connection with my comparison of gasoline consumption with that of Mr. La Schum, I stated that the gasoline cost was 33⅓ per cent of the total maintenance cost. I say that because, when an average man thinks of 33⅓ per cent of his costs being gasoline, he is apt to be critical of the oil company. In my consideration of this problem, as is shown in Table 4, I have included under fixed charges: Chauffeur and help, storage, insurance, license and depreciation, which constitute the 65.2 per cent of the total. Under variable charges, I have included gasoline, lubricating oil and grease, tires and road and miscellaneous expenses. When I get on the same basis that Mr. La Schum has considered and take into consideration gasoline, oil and grease, body and chassis repairs and garage expenditures, I find that my figures practically agree with those of Mr. La Schum; if anything, they are a little higher on the gasoline consumption.

Research Topics and Suggestions

With the present issue we plan to present under this heading each month a topic that is pertinent to the present field of automobile research, and is either of special interest to some group of the Society membership, related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing house for research information, we shall be pleased to receive the comments of members regarding the topics presented, and their suggestions as to what might be of interest in this connection.

INFORMATION SERVICE

THE importance to engineers of having readily available a part of technical information pertinent to the solution of their problems can hardly be overestimated. Such information forms a basis for the development of new ideas and makes possible the extended application of principles already established. Its usefulness is largely governed by its degree of availability.

There are those who prefer to launch a project or enter a new field of investigation entirely unaffected by that which has already been accomplished in identical or closely related fields of endeavor. But it is certain that a great majority of workers believe that thorough enlightenment is the first requirement; they desire at the outset to be fully informed as to past activities and through this information to be warned against the pitfalls that have retarded the progress of others.

In spite of the generally accepted validity of the above statements, however, each individual organization in the industry does not maintain and probably cannot reasonably be expected to maintain a complete or even very comprehensive repository for information. Although some have gone far in this direction by establishing extensive libraries and reference files, yet the vast majority still depend largely upon the efforts of the individual to glean his facts wherever he may, from sources that are often uncertain and scattered and, in some cases, inaccessible.

It was with a realization of these conditions and in consequence of a lively and increasing demand for technical information that the Society of Automotive Engineers' information service was established some years ago. It has since become an important part of the activities of the Research Department. From its inception, this branch has undergone a continued enlargement of its sphere of activities, as the demands made upon it have increased. It has always been its aim to render an important service to the members by making available, and readily so, any obtainable material of automotive and allied subjects that may be of particular interest.

Many requests for such information are answered on the day of their receipt; they may involve questions with which members of the research staff are familiar and that can be answered readily, or they may require references to books or other publications that are catalogued in the reference files. In this connection, it should be stated that, in addition to being entered in the reference files, all important articles in publications received each month are carefully perused and those of sufficient value are either mentioned or reviewed in detail in the Notes and Reviews column of THE JOURNAL. Reprints of articles on various subjects are sent to members who have expressed a desire for them.

Certain inquiries demand more extensive investigation than the type mentioned above, before they can be properly and adequately answered. For such work there is accessible the Society's library that contains a large number of books on automotive and related subjects and also a file of over 60 periodicals, both domestic and foreign. The use of this library is directly available to members. In addition, access may be had to other libraries, notably that of the Engineering Societies with its very extensive collection of publications. Furthermore, the Department has a file containing a great amount of technical information obtained by the research staff through personal consultation with various investigators who have seen fit to release the material for distribution. This file includes, besides printed documents from governmental and educational organizations, a large number of informal reports on various subjects.

Inquiries are frequently received that relate to subjects not covered by publications or documents at hand but that are of sufficient general importance to the membership to warrant making a special investigation. This involves correspondence as well as interviews by a member of the research staff. To illustrate: a firm recently addressed the Department, stating that trouble was being experienced in finishing the surfaces of piston-ring grooves to a high degree of smoothness and accuracy. It was explained that the ordinary forming tool leaves in the metal small ridges, whose initial wear in service being very rapid, causes looseness of the rings and corresponding leakage past them.

A number of letters, stating the above case, were sent to leading manufacturers with a request that any person who had available for distribution material of interest on this subject send it to the Department at his convenience. The returns from this inquiry and reports of personal interviews on the subject have been forwarded immediately to the inquirer. Furthermore, it is expected that sufficient material of general interest will be received to warrant its presentation in these columns at an early date. Obviously the success of an investigation of this type is very largely dependent upon a spirit of cooperation and helpfulness among engineers. This has been found to exist in a marked degree.

It is the policy of the Department to maintain, so far as possible, a direct contact with persons engaged in research, with a view to assisting them by furnishing needed information. This is often accomplished by personal visits by members of the staff.

It is hoped that increasing numbers of the membership will take advantage of the benefits of the information service and that the present hearty support of all will be continued.

Tractor and Plow Usage in the First Breaking of Peat Land

By J. Lyman Larson[1]

Minneapolis Section Paper *Illustrated with* Photographs and Charts

A TRACT comprising several acres of "tamarack" swamp, drained with tile the previous fall and cleared of stumpage the following spring, was utilized to obtain accurate information regarding the tractor and the plowing equipment required for the heavy operations of first breaking of the peat soil, which was from 5 to 7 ft. deep. The paper describes the equipment used, gives details of the procedure and presents the data that were obtained.

Three different types of tractor and two types of plow, the latter having either a marsh or a breaker bottom and equipped both with and without a furrow pusher were used. Specifications of the tractors and the plows are given and commented upon, graphs and tabulations of the results being presented also. Power requirements on timbered peat and on grass marsh are compared and the efficiency of the plowing equipment is discussed.

INFORMATION regarding the equipment necessary for peat-land farming is both meager and conflicting. This is true more particularly with respect to the preliminary operation of breaking and preparing the first seed bed. A tract of peat land under the control of the Minnesota Agricultural Experiment Station was being put under cultivation for drainage experimental purposes, in the spring of 1922, and the opportunity was therefore utilized to obtain accurate information regarding the equipment required for the heavier operations and the best methods for applying that equipment.

Fig. 1—The Character of the Original Timber and the Quantity of Stumps Removed

The tract selected comprised several acres of "tamarack swamp" drained with tile the previous fall. The peat on the tract was from 5 to 7 ft. deep and had carried a very heavy growth of trees, principally tamaracks, birch, elm and maple. The clearing was done between April 15 and June 15 and it was estimated that 50 cords of stumps per acre were removed. Fig. 1 shows the character of the original timber and the stumps. The holes left by the removal of the stumps and the soft spots left by the back filling of the drains were very considerable factors in all the cultural operations, more particularly in the first plowing. It was considered that the job was a fairly difficult one, but one that was thoroughly representative of the actual conditions which would have to be met by the farmer in breaking-up timbered peat land. Fig. 2 shows a tractor bogged at the beginning of the work and Fig. 3 a horse-drawn implement and team standing on this identical spot after it had been plowed and rolled. During the progress of the experiment, the water level below the surface of the peat was maintained at about 3 ft. at the lower end and 4 ft. at the upper end. The soil was fairly firm at the upper end of the tract, and had a considerable amount of sod; at the lower end, the peat was very soft and much torn and pitted by the removal of the stumps.

Fig. 2—How a Tractor Became Bogged at the Beginning of the Plowing Because of Insufficient Support

G. R. B. Elliott, who designed and was in charge of the general project, utilized a ditch that already was on the property and controlled the water at six different levels, with a 1-ft. difference between levels, the idea being to get accurate knowledge of the effect that the water level has on the crop. He obtained variations of from 400 to 1000 per cent due to water level. Weir boxes were installed in the ditch at various places; flash-board boxes were used inside the weir boxes to hold the water up to the desired levels.

Plowing Depth

A very important consideration in the first breaking of any land is the getting rid of trash and soft litter. On peat land it is also especially important to plow sufficiently deep to get under the deep underground rootstalks of marsh vegetation. A very large proportion of swamp plants are perennials that store food for the next spring's growth in thickened roots. For example,

[1] A.S.A.E.—Instructor in farm engines, University of Minnesota, St. Paul, Minn.

Fig. 3—A Horse-Drawn Implement Standing on the Same Spot

average conditions on peat swamps other than grass marsh. Hence, plows were chosen that would cut effectively to that depth; namely, plows with 16 to 20-in. bottoms. These required comparatively heavy tractor equipment. A total of five types of plow and three types of tractor were used.

One of the facts that caused the decision in favor of deep plowing was that of the second-year-crop condition of soil. Clover planted in the fall on an 8-in. plowing after a flax crop had attained a much ranker growth by the latter part of the following May on the soil that had been broken 12 in. deep the first year than on soil broken only 6 in. deep.

Type of Tractor

Three different types of round-wheel tractor were available. These varied in design, weight, width, operating speed and special equipment.

Fig. 4 shows a tractor properly equipped for marsh plowing. It has deep skid-rings on the front wheels, wide extensions, widely spaced angle-lugs and spade teeth on the driving wheels. This does not mean that

Table 1—Summary of Tractor Details

	Tractor		
	A	*B*	*C*
	14 [illegible]	[illegible] 26	12 to 20
	1 45	2 45	2 11
	2 77	4 30	2 75
	4 42	84	70
	12×42	12×42	12×54
	12×42	4 [illegible]	24×54
	[illegible]	[illegible]	[illegible]
	[illegible]	6 300	5 420
	1 484	1 575	1 583
	[illegible]	131	182
	4 07	4 [illegible]	3 [illegible]
	77 40	125 50	93 83
	Kerosene	Kerosene	Coal
	11	10	10
	1	1	3
	7	2	2
	3	2	3
			4
			16

Table 2—Summary of Plow Details

Details	Types of Plow				
	XB, 20-in.	*YM*, 20-in.		*XB*, 16-in.	*YB*, 16-in.
		With Jointless Furrow Pusher	Without Jointless Furrow Pusher		
[illegible]	20	22	22	16	18
[illegible]	1 013	905	805	927	805
[illegible]	Two	Two	Two	Two	Two
[illegible]	4	6	6	4	6
[illegible]	13-10	13-10	13-10	13-10	13-10
[illegible]	24	23½	23½	24	23½
Draft Adjustment	Triangular	Adjustable	Tongue	Triangular	Adjustable Tongue
Length of Plowshare, Point to Heel	33½	31	31	28½	25¾
Landside	Length, in.	69	60½	69	52
	Height, in.	6	6	6	3
Vertical Tangent Height, [illegible]	16	12	12	11	11½
Moldboard	Plow Point, in.	58	54½	55½	50
	Plow Heel, in.	32	27½	28	28

any particular tractor is better for this work; it means only that it has the proper equipment. Some of the tractors failed solely because they lacked the proper equipment for such work.

As the type and equipment of the tractors had as much to do with the quality of work done as did the character of plow drawn, the specifications of the tractors and their equipment are given in Table 1. For convenience, the tractors are designated *A*, *B* and *C*. The plows are designated *X* and *Y*, followed by *M* or *B* to indicate whether a marsh or a breaker bottom was being used; plow details are given in Table 2.

Tractor *A* was available from the beginning, but it was felt beforehand that it would not pull the plows; so, no attempt was made to use it on this part of the work. The horsepower indicated by the dynamometer readings made with the heavier tractors shows this opinion to have been correct. Tractor *A*, however, was used to help Tractor *B* by hitching it on in front as described later. The mode of attaching the dynamometer is shown in Fig. 5.

Tractor *B* did not come on the ground properly equipped in all respects, and its use cannot be considered a success. It was as powerful as Tractor *C* and, with similar wheel equipment, undoubtedly should have done the work just as well. Its rear wheels carry a much heavier load per square inch of bearing surface than do either Tractors *A* or *C* and, while carrying the same load

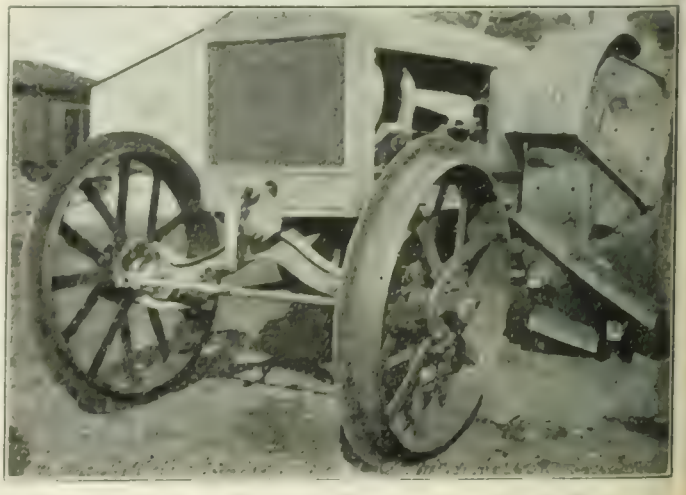


Fig. 4—A Tractor Properly Equipped for Marsh Plowing

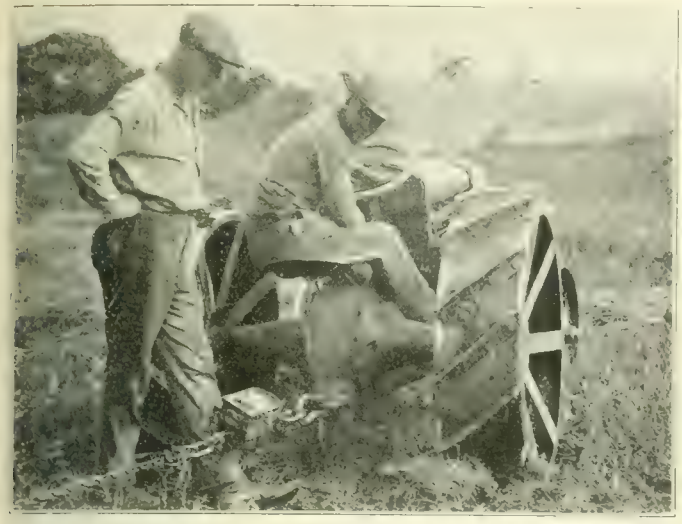


FIG. 5—METHOD OF ATTACHING THE DYNAMOMETER TO THE TRACTOR

per width of face, its front wheels were much smaller in diameter. The depth of skid rings on the front wheels was practically negligible. The material traveled over was very soft and slippery; consequently, the driver had little control over the direction of his machine and, when the front end plunged into the soft back-fill of a ditch or into the hole left by the removal of a stump, the tractor almost invariably mired and had to be pulled out with the help of Tractor *A*. Finally, Tractor *A* was kept hitched on ahead by a chain about 15 ft. long.

Tractor *B* was first hitched to a 20-in. *XB* plow and, at the instance of the factory operator, it was tried by running with the two right-hand wheels in the furrow. One length of the field was completed after much difficulty and miring, but the plow was not actually plowing at any time. After this, the drawbar of the tractor was pushed as far as possible to the right, while the hitch of the plow was thrown to the left. This permitted the tractor to travel on the sod or unplowed ground, but the best furrow that could be cut was about 6 in. in depth and there was a heavy sidedraft that tended to pull the

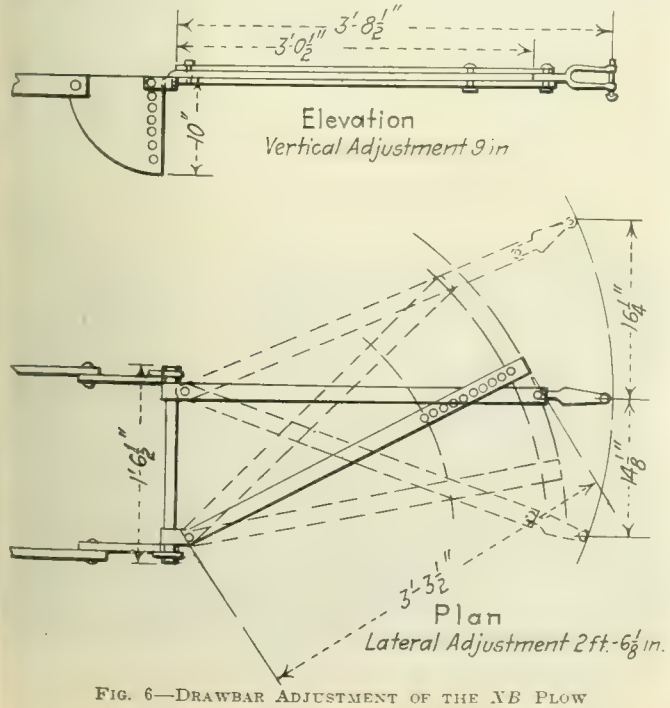


FIG. 6—DRAWBAR ADJUSTMENT OF THE *XB* PLOW

tractor into the furrow. As there was nothing to prevent the front wheels from skidding, this slewing of the tractor was serious. It is probable that by using a chain hitch, as was done later, the side-draft could have been eliminated partially. Figs. 6 and 7 show, respectively, the drawbar adjustments of the *XB* and the *YM* plows.

The greatest trouble was experienced in turning at the ends of the field. The front end of the tractor had no grip on the soft ground and, when a wheel fell into a hole, the force of the tractor would drive it still deeper into the far side. In trying to back the tractor, much the same thing happened and the rear wheels frequently mired by first cutting-up the sod with the closely set angle-lugs. Tractor *A* was then hitched on ahead to help in the steering and to prevent Tractor *B* from getting mired. This arrangement worked satisfactorily and the plow cut to a depth of 8 to 12 in. As these were not standard operating methods and as the proper wheel equipment could not be obtained readily to hold-up Tractor *B*, it was decided to discontinue the work in the

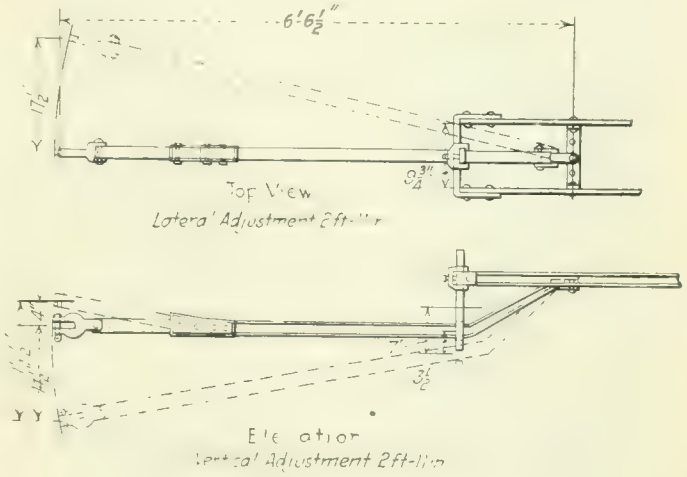


FIG. 7—DRAWBAR ADJUSTMENT OF THE *YM* PLOW

hope that a tractor could be found with approximately as much power but with less weight per inch of width of the wheels, one having the equipment necessary to make it operate successfully and with its drawbar designed so that it would permit the tractor to run on the sod and without undue side-draft. We were able to get a tractor that seemed to answer the requirements, the makers of which were willing to cooperate in the work under way. This is Tractor *C*. Fig. 8 shows the offset of the *XB* plow; that of the *YM* plow, equipped with a sod pusher, is shown in Fig. 9.

Profiting by previous experience, we asked for 12-in. extensions on the rear wheels, 4-in. extensions on the front wheels, skid rings on the front wheels 3-in. high, angle-iron lugs that would run clear across the face of the rear-wheel rims, placed with wide spacing; and 4-in. spade-lugs in pairs between the angle lugs. With the tractor used and owing to the comparatively light weight on the front wheels, it was found that it was not necessary to use the 4-in. extensions. Instead of hitching the plow directly to the drawbar of the tractor, as was the case with Tractor *B*, the drawbar was moved to the right almost as far as it would go and the hitch of the plow only slightly to the left. Then a 3-ft. length of chain was used to couple the plow to the tractor. This practically eliminated the side-draft on the plow. The hitch was made so that it could be dropped quickly and the

FIG. 7—THE OUTFIT OF THE *XB* PLOW

[illegible] exceeded 15 ft. In case of miring, the tractor could run ahead to a better footing, pull the plow through the soft spot and then back up to the short hitch. This method proved satisfactory and the work was finished in this way.

Figs. 10 and 11 are reproductions of the comparative dynamometer graphs showing the respective pulls of the 20-in. *XB* plow and the 20-in. *YM* plow equipped with a sod pusher. Figs. 12 to 20 are dynamometer graphs also, as follows: Fig. 12, the 20-in. *YM* plow without a sod pusher; Fig. 13, the 16-in. *XB* plow; Fig. 14, the 16-in. *YB* plow; Fig. 15, the 20-in. *YM* plow with sod pusher; Fig. 16, the 16-in. *YB* plow without a sod pusher; Fig. 17, the cutaway-disc implement equipped with eight discs of 20-in. diameter each, cutting to a depth of 7 in. in soft peat; Fig. 18, the 3500-lb. concrete roller; Fig. 19, the Martin ditcher; and Fig. 20, the 20-in. *YM* plow with a rolling coulter cutting a 9 x 22-in. furrow at variable speeds in uniform sodded peat.

As the plow when cutting a full size 12 x 20-in. sod sometimes caused a drawbar pull in excess of 2000 lb., it was thought that running in low gear might prevent miring. Several attempts were made to do this, but the interesting fact developed that the tractor mired far worse when running in low gear than in high. It would seem that the momentum of the higher speed or the short time the machinery rested on the soft footing permitted it to carry across the soft spots. The widely spaced angle-lugs and long spade-lugs gave a much better grip on the sod without cutting it up, than did the angle-lugs that were spaced more closely. Tractor *C* did nearly all the later work. It was found that after the ground was harrowed and rolled, Tractor *A* would handle the drag harrow, the log drag, the Martin ditcher or any of the lighter machinery; but it would not pull the heavy roller or the cutaway-disc implement loaded to cut to a sufficient depth.

PLOWING DETAILS

In connection with the plow details presented in Table 2, the first trial was made with a 20-in. *XB* standard breaker-bottom plow equipped with a standing coulter. This was the same plow that was used with Tractor *B* in the early plowing, using a rigid hitch. In the tests, however, a chain hitch was used and only one tractor, so as to eliminate all variables such as the speed and the difference in the hitch.

As stated in Table 2, which shows the power consumption of the plows while working in timbered peat, when cutting an 8 x 20-in. furrow, the 20-in. *XB* plow developed a drawbar pull of 1350 lb. in the tests. At a 10-in. depth, the drawbar pull increased to 1500 lb. for a 20-in. furrow and 1650 lb. for a 22-in. furrow. At a 12-in. depth, the drawbar pull was 1800 lb. for a 22-in. furrow.

The 16-in. *XB* plow had a standard brush-breaker bottom. It was tested at 8 in. of depth in firm peat and developed a 1050-lb. drawbar pull; at 10 in. of depth it developed a 1350-lb. drawbar pull. In soft peat, with a cut 10 in. deep, the drawbar pull required was 1200 lb. The furrow was 16 in. wide throughout.

The next plow used was a 20-in. *YM* marsh plow equipped with a furrow or sod pusher and a 24-in. rolling coulter. The center of the coulter was set 3 in. back from the point of the plowshare, and the cutting edge lacked 4 in. of penetrating as deeply. There was no adjustment that permitted a deeper or more forward setting. In use, soft roots were passed under the coulter in great quantity and clogged the throat after only a few feet of advance, as shown in Fig. 21. The rolling coulter was then replaced by a standing coulter. All later work on the timbered peat was done with this type of coulter. It is doubtful if the rolling coulter would have been successful in this type of ground, even had adjustments been possible. The plowing efficiency and power consumption of the 20-in. marsh plow at various speeds are shown in Fig. 22.

The sod or furrow pusher shown on the plowshare of the Type *M* plow in Fig. 23 is not, as may be supposed at first, merely a moldboard extension. It is a curved steel piece attached inside of the moldboard near the point of the plow and extending backward below and behind the moldboard on a level with the bottom of the furrow. It is cross-braced at the back against an enlarged and strengthened landside. It was developed largely in cooperation with the Agricultural Engineering Department of the University of Wisconsin, solely as an aid in marsh plowing. Its purpose is to push the freshly turned furrow still farther to the right, so that the next succeeding furrow will fall absolutely flat and then be pushed tight up against its fellow, completely covering the grass and other litter as illustrated by the finished plowing shown in Fig. 24.

The first trial with the plow was made with a rigid hitch, but this method had to be abandoned; when the driving wheels of the tractor dropped into a depression, the beam of the plow was carried down with them, thus burying the plow bottom and increasing the draft so that the tractor destroyed its footing and the whole outfit became mired. In the trial with this equipment, the sod cut was very uniform in size and the lay of the furrow slice very perfect. Cutting a 12 x 24-in. furrow required a pull in soft peat of about 1650 lb., and in the dense sodded peat an average of 1950 lb.

FIG. 8—THE OUTFIT OF THE *YM* PLOW EQUIPPED WITH A SOD PUSHER

The same plow was then tried without the furrow pusher. The pull was an average of 1650 lb. both on the soft and on the firm peat. Comparing the pull of the plow with and without the furrow pusher shows no increase in the soft peat, and a 300-lb. increase where a solid furrow-slice has to be pushed to one side. The increase in the power required was more than compensated for by the very greatly improved quality of the work done. During this trial, the drawbar of the plow was also shifted to give a direct draft. The pull required dropped 150 lb., but the tractor could only be held on the sod with difficulty.

In all the trials with the 20-in. *YM* plow, it was noted that soil packed in the center of the curve of the moldboard, particularly toward the front. Apparently this packing of the soil was due to a sharper curvature of the moldboard of this plow than of the others, for the other plows did not clog in the same way and no change in the hitch or the adjustment of this plow made it scour through the center except where the sod was more than usually firm and dense. Again referring to Table 3, the 16-in. *YB* plow was a standard brush-breaker bottom applied to the same frame and wheels as those of the 20-in. *YM* plow. At 18 in. of furrow width and 12 in. of depth, the drawbar pull was an average of 1250 lb., at 20 in. of width and a similar depth, the pull averaged 1350 lb.

Other Machinery

A very valuable implement for peat cultivation is the heavy roller for packing the seed bed. The one used was home made and is illustrated in Fig. 25; the roller was of steel filled with concrete and had a steel frame with a diameter of 3 ft., a length of 4 ft. and a total weight of 3500 lb. When moving the pull developed was an average of 950 lb.; however, when the roller stopped, it settled into the peat and, in each case, a pull of 2300 lb. was required to start it.

The cutaway-disc implement proved itself very valuable in breaking-up the seed bed. It was of the standard 5-ft. width and had eight 20-in. discs. It had to be loaded with about 200 lb. to make it cut 7 in. into the ground. The pull developed was 1050 lb., and a 1500-lb. pull was required to start the load. This machine, even when loaded to make it cut deeply, would not do good work with one passage over sod land. Wherever the

TABLE 3—POWER CONSUMPTION OF PLOWS IN TIMBERED PEAT

Type of Plow	Type of Soil	Size of Furrow, In.	Cross-Section, Sq. In.	Drawbar Pull, Lb.	Drawbar Pull, Lb. per Sq. In.	Speed, Ft. per Min.	Drawbar Hp.
XB, 20-in.		20x8	160	1,350	8.4	242	9.92
		20x10	200	1,500	7.5	242	11.03
		22x10	220	1,800	8.2	242	13.23
YM, 20-in. with Sod Pusher	In Soft Peat	24x12	288	1,650	5.7	242	12.13
	In Sod	24x12	288	1,950	6.8	242	14.34
YM, 20-in., Without Sod Pusher	In Sod and Soft Peat	24x12	288	1,650	5.7	242	12.13
	On Direct Pull	24x12	288	1,500	5.2	242	11.03
YB, 16-in.		18x12	216	1,250	5.8	242	9.19
		20x12	240	1,350	5.6	242	9.92
XB, 16-in.	In Firm Peat	16x8	128	1,050	8.2	242	7.72
		16x10	160	1,350	8.4	242	9.92
	In Soft Peat	16x10	160	1,200	7.5	242	8.82
Cutaway Disc		60x7	420	1,050	2.5	242	7.72
Roller				950		242	6.98
Maximum Pull on Plows				2,400		242	17.64

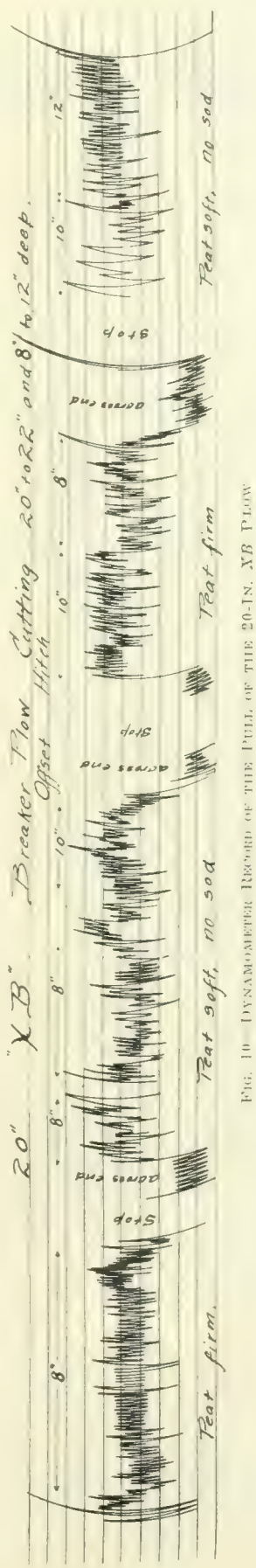


Fig. 10—Dynamometer Record of the Pull of the 20-in. *XB* Plow

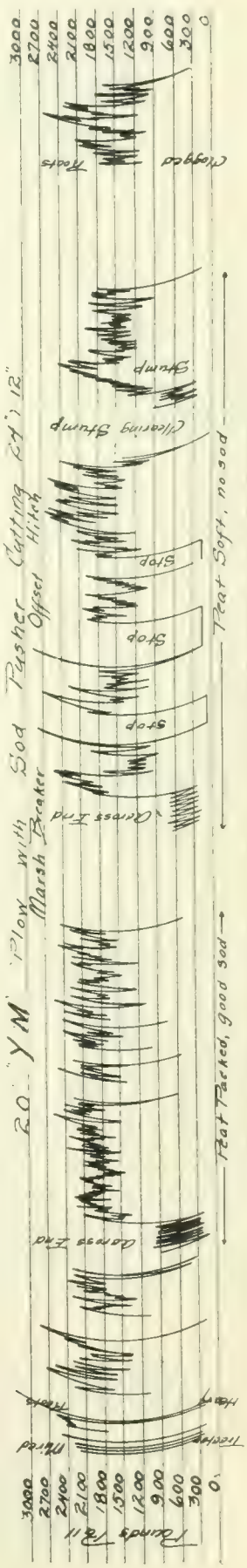


Fig. 11—Record of the Pull of the 20-in. *YM* Plow Equipped with a Sod Pusher

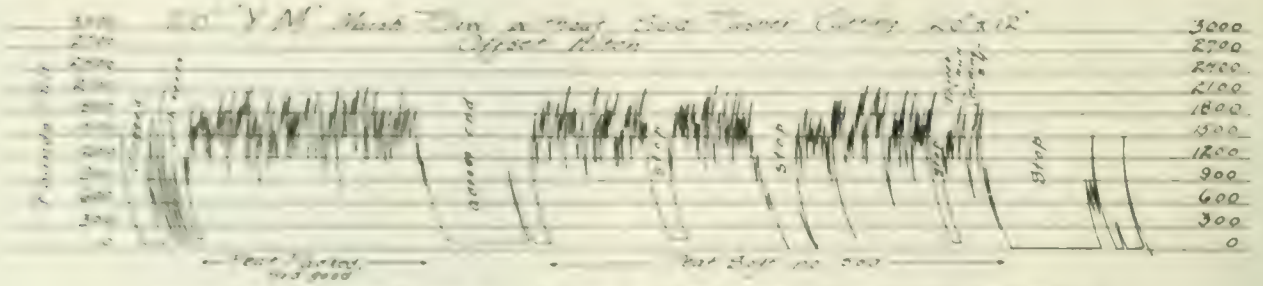


FIG. 11—DYNAMOMETER RECORD OF THE PULL OF THE 20-IN. *YM* PLOW WITHOUT A SOD PUSHER

were very tough or strong, the sod was not cut off in the bottom, but was rolled over with the roots still hanging. Five passages were required to do only fairly decent work. However, on the turned sod or where there was no sod, one passage gave very excellent results. All of the other machinery used in cultivation was comparatively light and could be drawn readily with horses or a 9-20 tractor.

TESTS ON THE OPEN MARSH

To obtain a comparison between the power required on timbered peat and that required on grass marsh, a level tract was chosen on which the vegetation was small

TABLE 4—POWER CONSUMPTION OF A 20-IN., *YM* PLOW AT VARYING SPEEDS

Speed in Grass-Covered Peat		Drawbar Pull		Power Consumed, Hp.
Ft. per Min.	M.P.H.	Total, Lb.	Lb. per Sq. In.	
192	2.19	950	4.79	5.55
245	2.78	900	4.54	6.68
333	3.78	1,000	5.05	9.82
522	5.93	1,070	5.40	16.61

sedge and grass. It was typical of the thinnest sodded peats in their natural condition. The plow used was the 20-in. *YM* plow with a rolling coulter and without a furrow pusher; it is shown in Fig. 26. In Fig. 27, the same plow is cutting a furrow of 9 x 22 in. cross-section, using a furrow pusher. A direct pull was used. On the timbered peat, this plow had given a drawbar pull of 5.29 lb. per sq. in. of cross-section of the furrow slice. Operating at the same speed and cutting a 9 x 22-in. furrow slice, the drawbar pull in the thin-sodded open-marsh was 4.54 lb. per sq. in. of the cross-section of the furrow slice, and the power expended was 6.68 hp. This is a decrease of only 12.70 per cent in favor of the thin-sodded peat and the rolling coulter. The rolling coulter operated with distinct success on this ground because of the absence of deep or heavy roots.

The tractor was then operated at varying speeds to test-out its plowing efficiency. In all, four speeds were used of approximately 2.20, 2.75, 3.75 and 6.00 m.p.h. It was found that the efficiency of the plow decreased with the slower speed and also with the higher, although, in the latter case, the greater drawbar pull must be offset against the greater acreage plowed per day. Table 4 shows the power consumption of the 20-in. *YM* plow at ranging speeds when cutting a 9 x 22-in. cross-section in grass-covered peat. Fig. 28 illustrates the completed work.

In conclusion, several important factors were brought out by the trials. What can be called the fundamental consideration upon which all the others are built-up is the better quality of work done by the heavier plows. This was confirmed later by the lessened weed growth on the deep plowing. During the summer, nettles were plentiful on the shallow plowing but not on the rest of the field. The manner in which the land was cultivated later did not permit tests for crop yield on the various depths. It is not assumed that deep plowing on new peat will help the crop yield the first year; the reverse is probably true. There is no question, however, that it gets rid of the old growth and puts the land in better condition forever after. Throughout the whole test, the larger plows did better work than the small ones and gave a more complete turning of the furrow.

The rolling coulter as it was equipped was certainly not a success on the timbered peat, and it does not appear how it can be made a success on peat containing roots too heavy to cut or so soft that they will bend easily. To be got rid of, these roots must actually be torn out of the ground. On open marsh sodded with shallow rooting, small sedges and blue-joint grass, the 24-in. rolling coulter was a success, and possibly a smaller plow would also be satisfactory. In marsh containing reeds and the larger sedges, it probably would be necessary to have the coulter sufficiently large to penetrate below and forward of the point of the plow, in this manner either cutting off fibrous roots or carrying them into the bottom of the furrow.

The furrow pusher was a distinct success. It did not add as much to the draft of the plow as was expected; it pushed the newly turned furrow out of the way and

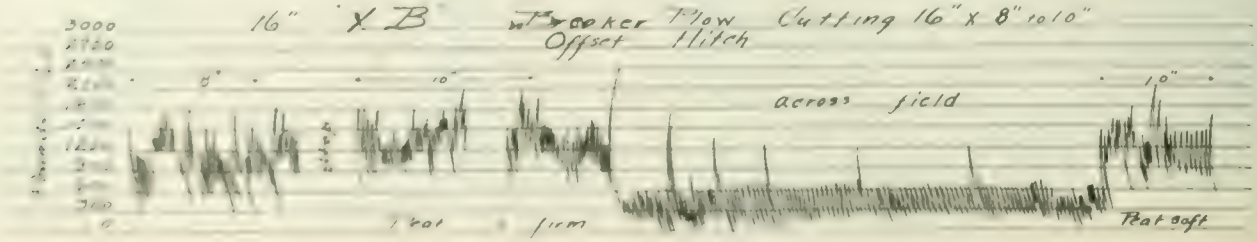


FIG. 12—TRACE MADE BY THE DYNAMOMETER OF THE PULL OF THE 16-IN. *XB* PLOW

permitted the more complete turning of the sod and the elimination of top litter.

Power Required

An analysis of the power consumption developed several interesting facts. On the larger plows, the drawbar pull was almost constantly near or above 10 hp., with a reserve up to 17 hp. that was drawn upon at times. For the smaller plows, the power consumption was above 8 hp., with a reserve up to 15 hp. that was called upon at times. From this it would appear that, for marsh breaking, a tractor is necessary that is capable of developing not less than 12 hp. as a working drawbar power, with a reserve above that. This power and a power-reserve is not necessary for later plowing.

Special Wheel Equipment

Ample support to the tractor proved to be just as important as power. Tractor *B* failed rather signally, not

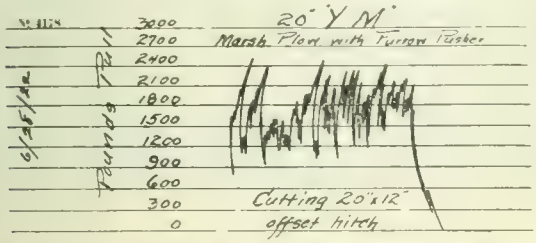


Fig. 15—Another Record of the Pull of the 20-In. *YM* Plow Equipped with a Sod Pusher

from any inherent defect in the design of the tractor itself or from a lack of power, but because the special wheel equipment that would enable it to do its work was not available. It was like a strong swimmer thrown into the water and told to swim with stones tied to his head and to his feet. It was capable of developing only about a 1600-lb. drawbar pull without miring, though it was able to do much more on hard ground. It not only mired its front wheels but, when the plow stuck, the closely spaced angle-irons on the driving wheels cut the sod, which was then thrown backward. leaving the tractor mired. Tractor *C* had a much larger supporting area, carrying less weight. The angle-lugs were spaced twice as far apart as on Tractor *B*. It tore out its footing and mired uniformly when exerting a pull of 2400 lb. This gave it 50 per cent more power in an emergency than Tractor *B*, though Tractor *C* was of lower rating. The spade teeth served a very useful purpose in catching and holding on submerged roots or timber in pulling out of a hole. The heavy skid-rings gave the driver control of his machine on soft ground.

This special equipment is not in any degree complicated or expensive. It easily can be made standard, to be attached to the tractor by the operator for soft-ground

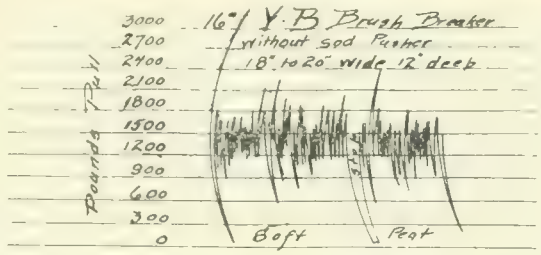


Fig. 16—Dynamometer Record of the Pull of the 16-In. *YB* Plow without a Sod Pusher

conditions. There are many tractors now owned throughout the country that cannot be operated profitably in the early spring or in wet weather. This is especially true in the working of peat land. Yet peat land can be cultivated, even at its wettest, without injury to the seed bed. It can be plowed in the spring and seeded, while the clay upland is still too soft. This is an extremely important factor in financing farming operations as well as in general farm efficiency. It seems logical that the wider wheel equipment be made standard for the wetter and softer districts and furnished upon the advice of the tractor dealer. It is also probable that, in many cases where tractors are now unprofitable on soft lands, an expenditure of $100 would change an unprofitable into a profitable investment.

Total Power Consumed

In calculating the power consumed per unit of cross-sectional area, the 16-in. plows give almost the same results as the 20-in. plows of the same make. This is not what was expected, as it was thought that the vertical cut would offer a higher proportional resistance than the bottom cut. Apparently, this was not the case, for

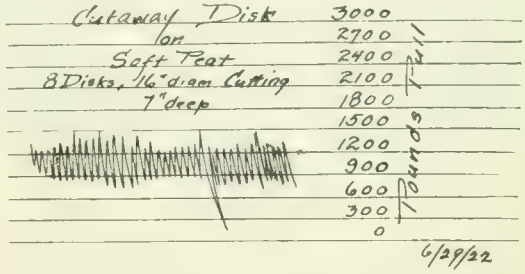


Fig. 17—The Record Made by the Dynamometer of the Pull of the Cutaway Disc Implement Equipped with Eight Discs When Cutting to a Depth of 7 In. in Soft Peat

the 20-in. plow gave no greater efficiency than the 16-in. plow of the same make.

There was an apparent advantage in efficiency in one make over the other. This is not thought to be due to any difference in the design of the plow bottoms themselves. In the case of the *XB* plow, however, the angle between the drawbar and the plow itself when

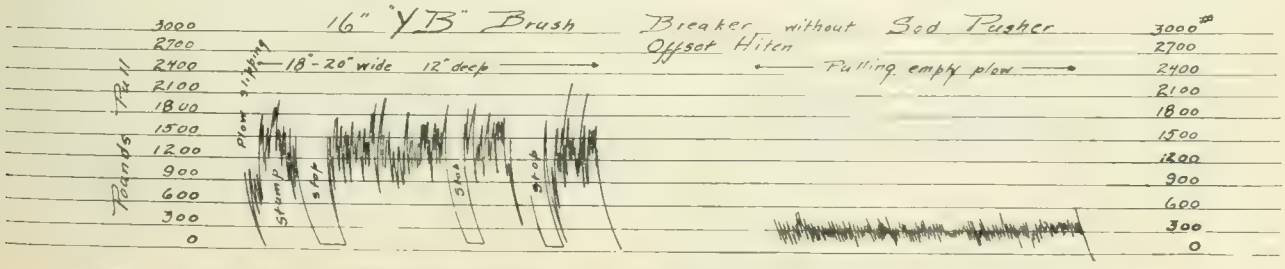
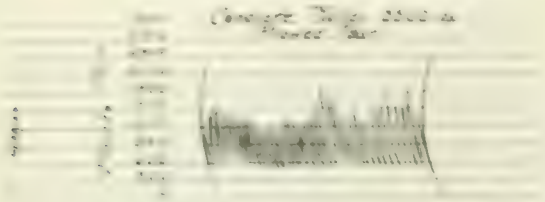


Fig. 14—The Pull of the 16-In. *YB* Plow Is Shown in This Reproduction of a Dynamometer Record

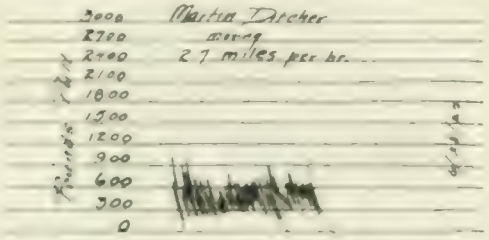


[illegible] is shown as that [illegible]

[illegible] was 18 [illegible] 20 min., while that of the *YM* and *W* plows when working was 10 deg. 38 min. Of the [illegible] pulls on the two plows, the horizontal components parallel to the line of draft were, respectively, [illegible] and 3.05 lb. per sq. in. of cross-section of the furrow slice. These figures compare favorably with the pull developed by the *YM* plow operating on this [illegible] peat with a direct pull, but bring out the great loss in power through friction and otherwise due to the angle of draft of the offset hitch.

The general proposition was established that for ordinary sod breaking, the horsepower required can be figured readily and with fair accuracy on the basis of a 5-lb. pull per sq. in. of the furrow slice. Multiply that by the speed it is proposed to travel and then calculate the horsepower in the ordinary way.

From the standpoint of mere efficiency in turning soil, the cutaway-disc implement loaded to cut 7 in. was far ahead of any of the plows. In fact, its power consumption per unit of cross-sectional area turned was less than one-half of that of the plows. Its use, therefore, is strongly to be recommended under conditions where its use is practicable. It cannot be recommended for first breaking instead of using plows, since it required about five passages of the disc-implement to give results



[illegible] the Martin Ditcher Moving

equivalent to one plowing. The results of the work seem to indicate that the disc-implement may be extremely efficient for all later cultivation.

The roller gave some remarkable results. Not only did it pack the peat and so form a better root bed but, after the ground has been plowed, harrowed and rolled, even that part which was originally so soft and full of holes that it was difficult to get the tractors through became sufficiently firm to support horses for all later cultivation.

THE DISCUSSION

A. F. MOYER:—On what basis is the calculation made for power consumed per unit of cross-sectional area? Is it calculated on the width of the drive wheels and the amount of weight distributed on the drive wheels?

J. L. LARSON:—If we were to calculate the area and number of pounds per square inch on the drive wheels according to the depth they sank, the result would be about $2\frac{1}{2}$ lb. per sq. in. for Tractor *C* in sinking 2 in. into the ground. A 1400-lb. horse will exert a ground

FIG. 21—A QUANTITY OF SOFT ROOTS THAT PASSED UNDER THE ROLLING COULTER AND PILED UP IN FRONT OF THE PLOW

pressure of about 15 lb. per sq. in., that of a man being about 6 lb. per sq. in. Tractor *C*, weighing 5000 lb. at a rough estimate, would exert a ground pressure of about 75 lb. per sq. in. The sinking into the ground would amount to $2\frac{1}{2}$ lb. per sq. in.

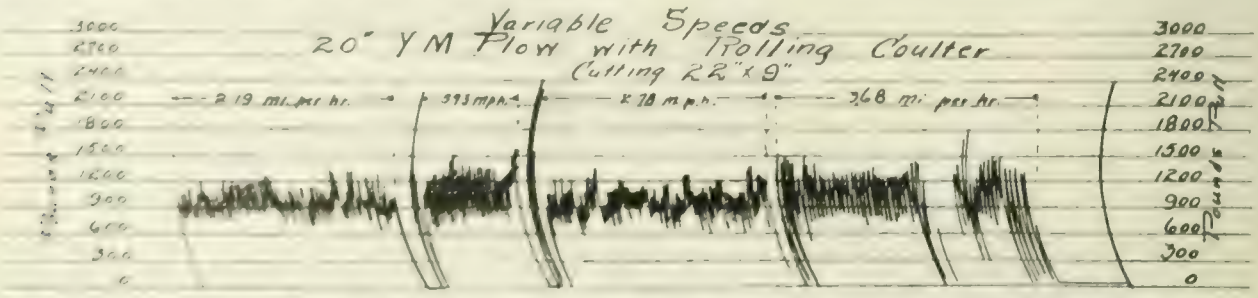
G. R. B. ELLIOTT:—An interesting point brought out is in regard to the drawbar pull per square inch of cross-section of the furrow slice. When the furrow slice is too large or too small, the drawbar pull per square inch increases even though a decrease in the size of furrow slice may cause a decrease in the total drawbar horsepower.

GEORGE SYKES:—Would it not be better to increase the size of the roller?

MR. LARSON:—The concrete roller weighs about 3500 lb. and is very necessary on peat land. It is a question whether it would be practicable to increase that weight to any extent. We want to carry all the weight we can and yet have no slippage.

MR. MOYER:—Would that not depend on how the weight is distributed over the tractor?

MR. LARSON:—We found that to be a very important consideration. Many things must be taken into consideration when designing a tractor for soft land, and it is not as easy a proposition as it would seem to be.



[illegible] THE 20-IN. *YM* PLOW EQUIPPED WITH A ROLLING COULTER WHEN CUTTING [illegible] AT VARIOUS SPEEDS IN UNIFORM SODDED PEAT

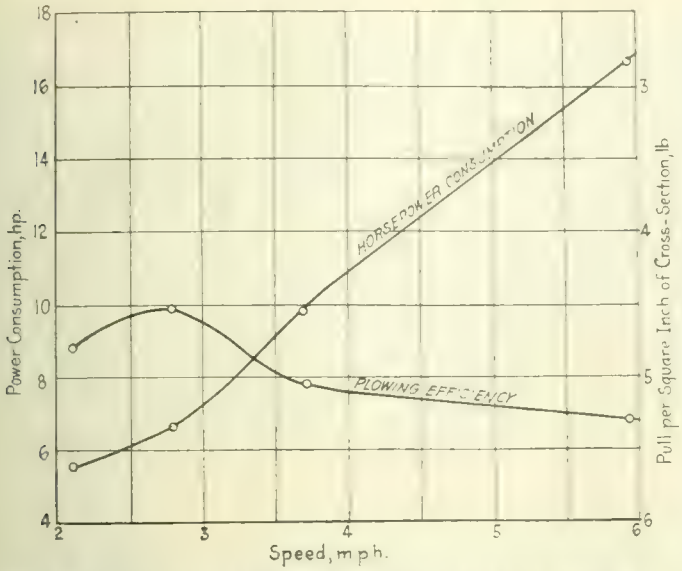


FIG. 22—CHART OF THE PLOWING EFFICIENCY AND THE POWER CONSUMED BY THE 20-IN. MARSH PLOW WHEN WORKING IN PEAT AT VARIOUS SPEEDS

MR. MOYER:—Have you in your observations, not necessarily in your measurements, observed the effect of the wheel diameter?

MR. LARSON:—We found the larger wheel-diameter much better than the narrow or small wheel.

MR. SYKES:—Why is the roller made so small in diameter?

MR. LARSON:—The main reason is that we used the only available steel casing we had.

MR. ELLIOTT:—We wanted to get as near as possible to a weight of 1000 lb. per linear ft. of width of the roller.

MR. MOYER:—Is that at only one speed?

MR. LARSON:—That was taken at 2¾ m.p.h.

MR. SYKES:—Would it not be of advantage to have a larger diameter for the roller?

MR. LARSON:—Not necessarily. We want to keep the weight down and still pack the ground sufficiently hard. We think the roller we used does this.

MR. MOYER:—How do you express plowing efficiency?

MR. LARSON:—By the number of pounds required per square inch of furrow slice.

W. G. CLARK:—Was this work purely experimental?

MR. LARSON:—Yes.

MR. CLARK:—Have you any basis for stating the cost of doing this work?

MR. LARSON:—Not yet, but we did much more work on this plot of ground than we think would be necessary for the farmer. I doubt if the farmer can afford the expense. Most of it would be done by the farmer at the time of the first breaking. However, it is absolutely necessary that he does some of the things we did.

MR. CLARK:—It would need to be cheap land.

MR. LARSON:—The land needs to be cheap and it is cheap. Within the next 5 years it will be surprising how much of this land is plowed up. It raises a very good crop; in fact, our best seed potatoes come from peat land.

MR. CLARK:—What other crops are particularly adapted to peat land? Will the crop pay the expense?

MR. ELLIOTT:—About two-thirds to three-quarters of the ordinary farm produce will do better on peat land properly cultivated than on up-land; the remainder will not do so well. Corn, potatoes and rye do especially well, but wheat will not do anything. Oats in this part of the Country will produce nearly twice as much. Nearly all grasses and clover for hay do excellently well. Most truck and garden crops do especially well. Onions should range from 500 to 600 bu. per acre and I know of one crop of more than 1100 bu. to the acre. Carrots returned us 600 bu. to the acre. Both of these were grown where the water was held 6 ft. below the surface. Sugar beets gave 20 tons to the acre, yielding 17.8 per cent of sugar. Where the water is held near the surface, root vegetables are apt to "finger" badly.

FIG. 24—HOW THE FURROW PUSHER OPERATES TO PUSH THE FRESHLY TURNED FURROW TO THE RIGHT SO THAT THE SUCCEEDING FURROW WILL FALL FLAT AND BE PUSHED TIGHTLY AGAINST IT, THUS COVERING THE GRASS AND OTHER LITTER COMPLETELY

FIG. 23—THE MARSH OR *M* TYPE OF PLOWSHARE EQUIPPED WITH A FURROW PUSHER

A. H. BATES:—You mentioned an 18-deg. angle of hitch.

MR. LARSON:—One is 18 deg. and the other is 10 deg. The 18-deg.-angle hitch is on the *XB* plow and the 10-deg.-angle hitch is on the *YM* plow. With this angle of side-draft, it gave approximately 150 lb. more pull than on a straight draft.

MR. MOYER:—What effect is caused by the plow having side-draft?

MR. LARSON:—We did not have the opportunity to measure it on the tractor, but it had its effect.

MR. MOYER:—Was it less marked on the tractor?

MR. LARSON:—I think it would be. Of course, the tractors had sufficient excess power. Side-draft did cause hard steering at all times, but it was less serious with Tractor *C* than with the others, due to its extreme narrowness.

MR. SYKES:—At what speed do you obtain the most efficient work?

MR. LARSON:—At a plowing speed of about 2¾ m.p.h.

Fig. [illegible] Caterpillar Rubber Equipped Tractor Employed To Pack the Soil Pad

MR. MOYER:—Do you disregard the number of acres covered per day?

MR. LARSON:—Yes, so far as present calculations have gone.

MR. SYKES:—At a plowing speed of 1¾ m.p.h. would the equipment sink in the bog?

MR. LARSON:—Yes, the possibility of miring is doubled by running at slow speed; we can plow better and plow more ground at the 2¾-m.p.h. speed.

MR. MOYER:—Have others had a similar experience on other types of land? In field experiments, I observed that the resistance will usually increase as the speed increases.

MR. LARSON:—The surface of a bog is like rubber or tar, the faster the equipment moves over it, the less impression it makes.

MR. MOYER:—Time is an element in depression and I

Fig. [illegible] Type F Track Equipped with a Rubber Covered Roller in Test Over Peat

presume that, with a higher speed for a short length of time, the equipment would not sink so deep.

MR. LARSON:—Our experiments seem to indicate that [illegible] as far as miring goes.

MR. MOYER:—A bog has a certain resilience.

MR. SYKES:—Are the lugs on the drive wheels used as a result of special experiment, or are they standard?

MR. LARSON:—They were put on specially but are standard. Up to about 2 years ago some of the same equipment was not standard, but this equipment had been made standard by what has occurred when we carried on our experiments. Tractor builders who put their tractors in the rice fields gave it considerable thought, and I think [illegible] with regard to peat land.

MR. SYKES:—Do you think the equipment suitable for rice fields will be suitable for peat land?

MR. LARSON:—No, but some of the same principles that apply to rice land apply to peat tillage. We want to avoid turning-up the ground very much, but still get well into the soil, for the purpose of obtaining traction.

MR. MOYER:—Information of this kind obtained under actual operating conditions is always valuable, enabling engineers to analyze their problems to much better advantage, but in considering certain data that Mr. Larson has presented graphically, a question arises as to the proper expressions and definitions for the quantities involved. Although I am not familiar with the usage of agricultural engineers, the expression "plowing efficiency" seems to be open to at least an academic criticism as to the meaning that has been given to it. "Efficiency" in engineering mechanics is always defined as

Fig. 27—Rear View of the *YM* Plow Equipped with Sod Pusher That Was Illustrated in Fig. 9 Turning a 9 x 22-In. Furrow

the output divided by the input and usually involves quantities of energy expended and work accomplished. Its denomination is usually in percentage, but it is expressed in square inches per pound in the relation between the furrow section and the drawbar pull that Mr. Larson has plotted as "plowing efficiency." Would it not be better to invert this quantity and call it "specific draft," "unit draft" or some such more accurate name expressed in pounds of draft per square inch of furrow section? It is certainly an important quantity to consider in studying the draft of plows and should be given a name that is accurately descriptive.

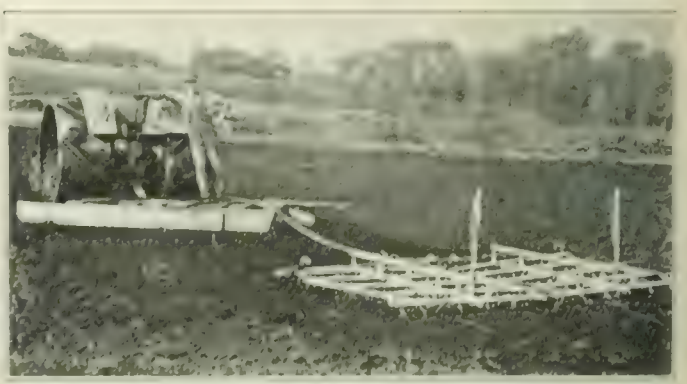


Fig. 28—How the Land Looked After the Plowing Was Completed and Had Been Gone Over with a Ground Smoothing Attachment Followed by a Harrow

Mr. Larson has used the qualifying words that this quantity denotes plowing efficiency "without considering the number of acres plowed per day," which raises the question: What would be the plowing efficiency if one does consider the number of acres plowed per day? And not only should we consider the number of acres per day, but the depth of plowing as well. Returning to the definition of efficiency, it seems that we might include all of these considerations by calculating some such quantity as cubic feet of furrow turned per drawbar horsepower per hour. This would be a true measure of plowing efficiency and is very nearly in proportion to plowing cost when depth is considered and human labor per horsepower is fixed.

If the data shown in Mr. Larson's curve of "plowing efficiency" or, preferably, "specific draft" were recalculated according to the above proposed definition of plowing efficiency, there would no longer be a "peak" in the revised graph at 2¾ m.p.h., but only a slight flattening of the curve as the speed is increased, showing that the gain in efficiency is less rapid beyond that speed; but a gain is nevertheless available up to speeds much higher than those commonly used. Since it is evident that this difference in viewpoint will show a rising efficiency with an increased speed in certain ranges where a falling efficiency has been shown, it is important to be specific in our definitions. It would be extremely interesting if Mr. Larson would reply to this discussion and, if he sees fit, prepare a curve of plowing efficiency as above defined, referred to speed.

EXPORTS AND IMPORTS

IT has been known to students of the subjects for a good many months past that far-reaching changes of proportions and relations were in progress in the commercial (and financial) interchanges of the United States with the rest of the world. It had become clear before the fiscal year 1922-1923 had far advanced that important shifts of emphasis were occurring on both the import and the export side of the account. The most impressive of these, of course, was the remarkable growth of the value of the imports in proportion to the value of the exports, particularly when the large net balance of imports over exports of gold and silver was taken into the reckoning. Indeed, the fiscal year had run scarcely half its course before it began to appear possible that for the first time in nearly three-quarters of a century we should in 1922-1923 as a whole have an excess of imports rather than exports in our total visible interchanges with other nations. Particularly striking though this great change was, however, it was by no means the only shift of economic significance that began to reveal itself in our import and export figures soon after the last fiscal year began. It was early observable that the values of our imports of crude materials for use in manufacturing and of manufactures for further use in manufacturing were swelling very rapidly, while the value of our imports of manufactures ready for consumption was not increasing at anything like the rate that had been predicted by many protectionists or that might naturally have been expected in view of the extensive rise of the price level in the United States. On the other hand, the export figures, when analyzed showed a progressive increase in the proportion borne by the value of the exports of products of manufacture to the total value of the exports, accompanied by a progressive proportional decrease of the value of the exports of foodstuffs and raw materials. In other words, as the past fiscal year progressed the foreign trade of the United States came more and more to present a general appearance similar to that normally presented before the war by the trade of the leading industrial nations of Europe—above all Great Britain. Like those nations in the pre-war years we had what is commonly, though unscientifically, described as an "unfavorable" or "adverse" balance of trade in our total visible interchanges with the rest of the world, and at the same time our manufacturing industries were playing an ever larger part in determining the inflow and outflow of commodities and goods.

On our total exchanges of merchandise with other countries during the first 11 months of 1922-1923 there was a "favorable" balance; that is, an excess of the value of the exports over that of the imports, in the amount of $175,315,362, whereas in the first 11 months of 1921-1922 the "favorable" balance on merchandise account was the very much larger amount of $1,088,421,629. The latter of these figures fairly corresponds, if due allowance is made for changes in the level of prices, with the normal "favorable" balance shown by the trade of the United States in the pre-war years; but evidently the figure for 1922-1923 represents but a mere fraction of the "favorable" balance to which we were formerly accustomed. Moreover, we by no means get the whole story of the change that has occurred from the figures of our imports and exports of merchandise. Besides these the values of our imports and exports of gold and silver must be reckoned with. The total inward and outward movement of the precious metals during the period of this year yielded an excess of imports in the amount of $221,936,550, against an excess of imports of the precious metals totaling $437,245,407 for the period a year ago. Here the important thing to note is that when we set the 1922-1923 net import balance on account of gold and silver over against the year's net export balance on merchandise account we are left with a final net import balance in the amount of $46,621,188 on the Country's total "visible" interchanges with the rest of the world during the 11 months' period, whereas a year ago, notwithstanding the considerably larger net importation of the precious metals, our total "visible" interchanges with other countries still showed an excess of exports over imports in the amount of $651,176,222, a "favorable" balance far smaller, of course, than those which were usual from year to year during and immediately after the war, but nevertheless on its face normal enough by the pre-war standard.

The two groups or classes of imports which made really large gains in value in 1922-1923, as compared with 1921-1922, were crude materials for use in manufacturing and manufactures for further use in manufacturing, while the group designated as manufactures ready for consumption increased only insignificantly. The figures undeniably indicate a remarkable state of activity and prosperity among our industries, necessitating the importation of raw material and semi-finished products upon a quite unprecedented scale. The change in the conditions of the Country's foreign trade during the past fiscal year was not attended by a diminution of the ability of our industries to compete with those of other countries.—A. R. Marsh in *Economic World.*

The Testing of Materials and Its Effect on Engineering

By C. B. Upton

BUFFALO SECTION PAPER

The development of the automobile has brought with it and has put into commercial practice new materials and new methods of control of material, especially in alloy-steel and the light metals, and has altered machine design by emphasizing the importance of allowing for fatigue, stiffness and shock-resistance as coordinate in importance with strength. Progress has been concerned chiefly with the construction and operation of the engine, with the methods of manufacturing the parts and with the properties of the materials of which the parts are composed. Inseparable from quantity production is the system of gaging and inspecting the size and shape of every part manufactured. Another kind of inspection is that of checking the properties of the materials.

The former method of testing a test-piece to destruction has been superseded by that of testing every finished part without injury being done to the part. Strengths and working stresses now are commonly as high as five times those of a generation ago. Machinery is correspondingly lighter, the range of operation wider and the cost of operation lower. Light alloys of aluminum or magnesium base, unknown a generation ago, have come into use, and a new cast-iron with more than the strength of ordinary gray cast-iron and having some ductility and very appreciable shock resistance has been produced. Elastic-limit, in its former sense, soon will be relegated to an unimportant place and, for it, will be substituted the broader term "fatigue failure"; an "endurance curve," plotted as the logarithm of stress against the logarithm of the number of cycles needed to break, will show the relation in a perfect piece by a nearly straight line. Internal uncleanliness and external roughness will increase the downward slope of the curve. No definite correlation seems to exist between the fatigue elastic-limit and the proportional elastic-limit or the yield-point.

In some of the copper-rich alloys, the fatigue elastic-limit probably will be found to be higher than either the proportional elastic-limit or the yield-point. Among non-ferrous metals the fatigue limits are low. Tests of duralumin could be made. Through such researches as those of Professor Coker in England, who makes photo-elastic measurements by polarized light passing through models of transparent material, the effects of fillets, changes of section, keyways, couplings and the like are coming to be appreciated better. The weakening of a piece by a scratch or a groove has been found to be a function not only of the ratio of the depth of the scratch to the radius at the bottom of it, but also of the ratio of the depth of the scratch to the thickness of the piece. A scratch or a groove becomes relatively more serious, the smaller the piece. Endurance curves of sheet metal are affected greatly by surface imperfections that are relatively large compared with the thickness of the piece.

Although one pays the light metals in the ratio of strength to weight for tension loading only, a question not of strength was the controlling factor in design, whereas all these should have been given first place. At present, the first approximate sizes of many parts are of shapes of material are, in their order of importance, stiffness, fatigue-resistance, strength and shock-resistance. In truck work, strength comes higher. The particular requirements of each part should be investigated. In many parts in which stiffness is essential, such as the crankshaft, case-hardened low-carbon steel would give adequate strength and hardness and would be cheaper, easier to forge, machine and heat-treat than would alloy-steel. Strength should not be the only factor of safety considered in design; there should be as many factors of safety as there are bases of design; strength, fatigue, stiffness, shock.

ENGINEERS who are interested in the progress of their profession will find the story of the automobile during the last 20 years fascinating. The automobile has brought with it and has put into commercial practice new materials, new methods of control of material, especially in alloy-steel and the light metals, and the heat-treatment of metals for high strength; has altered machine design by emphasizing the importance of allowing for fatigue and for stiffness or shock-resistance, as being coordinate with the design for strength; and has made obvious the necessity for considering inertia-stresses in the design of moving machinery. The scientific design of bearings and lubrication will perhaps be the next boon to general engineering knowledge to come through the automobile; it has not yet arrived, but is pending.

There have been three parallel lines of development in the progress of automotive engineering; (*a*) the theory and practice of the construction and operation of the prime-mover, or engine, used; (*b*) the improvement of the manufacturing methods for producing and shaping the materials of construction, and for assuring the desired shape, size and proportion of different parts; and (*c*) the radical and important improvement of the properties of the materials of construction that makes possible the most astounding reductions in the sizes and the weights of parts.

The improvement of production machinery, such as forges, presses, lathes and milling, drilling and grinding machines, that makes possible the modern system of "interchangeable" quantity-production, is in itself a wonderful piece of engineering work. Inseparable from it is the system of gaging and inspecting the size and shape of every piece manufactured. Another kind of inspection, upon which we have made probably only a beginning, is the check on the properties of the materials, a discussion of which comes properly under the title of this paper.

Not so very long ago, material inspection was done mainly by tests to destruction of an occasional piece that was shunted out of production. A certain fraction of the current product was set aside for such tests, usually 1 piece in 100 or 1000, but a sufficient number to be considered typical of a run, a "heat" from a steel-furnace or a similar quantity. If the test-specimens that were selected passed the destruction test, all their companion pieces were accepted; if the test-specimens failed, further

tests were made to check the first results and to decide upon the acceptance or the rejection of the lot. At present, though such testing to destruction of selected pieces has not been abandoned, this scheme belongs rather to the preliminary research stage; and, in the course of production, the checking of material is done best by tests that can be applied to every finished part without injury being done to the part. Future progress in the control of material will lie largely in this inspection; for example, the present Brinell and scleroscopic tests of hardness are unlikely to survive the next 10 years as, in practice, both have too many obvious defects both of theory and of performance.

For a broad and detailed discussion of the relation of the engineer to materials and material-testing, I recommend a recent book on Engineering Steels, by the English engineer, Leslie Aitchison. He points out that the demands of the automotive industry for steels capable of withstanding the higher stresses have made it imperative for engineers to ascertain, before using them, that the steels really possess the expected and desired properties; hence, there is a critical re-examination of what are, fundamentally, the properties the engineer needs for specified purposes, and a development of better means for measuring those properties. Specifications are often broadened to cover the chemical composition, heat-treatment, macrostructure and microstructure, as well as the physical properties, strength, ductility, hardness and the like. When we begin to broaden specifications in this way in attempting to tie the case up tight, to obtain absolute assurance that we shall get what we want, we admit that we do not know exactly what we do want, or how to state that want simply and in measurable terms. We should be able to make a specification in terms of three measurable properties, certainly not over four, and to state the tolerance limits for each so that the finished material shall be exactly what we want without restriction as to how it is made or what it is made from. We do not now have such a knowledge of materials. At present we need improvement in our knowledge of the properties of materials rather than improvement in the properties themselves.

Comment on the actual improvements in the properties during what may be called recent times is hardly in point here, as the past and current values are so well known. Our fathers worked with structural and machine steels of carbon-steel composition, and used them, in general, without heat-treatment. We use heat-treatment and alloy-steels very commonly and get strengths and working stresses of an order as high as five times those of a generation ago. Correspondingly, our automotive machinery is lighter where weight was formerly required; and, in consequence of lower weight, the range of operation has been widened and the cost of operation lowered. As L. H. Pomeroy recently has pointed out, a saving of weight in one place has cumulative effects throughout the car. We also have a new set of materials with which to deal in the light alloys of aluminum or magnesium base, which were unknown a generation ago, and the heat-treatment of them promises to be as important as the heat-treatment of steel.

In the field of cast iron, new material should be evolved in the near future. In the course of experiments on the quick conversion of white cast-iron into malleable cast-iron, it has been found possible, by a process taking but a few hours of heat-treatment, to make a material having a gray fracture due to "temper graphite," with a tension yield-point of about 45,000 lb. per sq. in., a maximum strength of about 75,000 lb. per sq. in. and some ductility. This new material is practically a gray cast-iron of about three times the strength of ordinary gray cast-iron, with some ductility, and with a very appreciable shock-resistance. It seems well worth investigating as a material for parts such as timing gears, inserted cylinder-sleeves and the like and, in general, for parts of not too complicated section, for which a cast iron of higher strength and stiffness than those of gray iron might be usable. This new material should be cheaper than malleable cast-iron.

Properties of Materials

In studying the properties of materials and learning what we should measure and specify as significant properties, it seems that the elastic-limit, as "proportional limit," or "Johnson limit," or the like, is soon to be set back to a very unimportant place. This property is not strictly a fundamental one; it is an accident of the manufacturing process, or largely of the particular history of the piece. We are interested in elastic-limit in two ways. If a part changes shape under service stresses, normal or abnormal, with a permanent set that is greater than the limits of the accuracy of machining and assembling, the part ceases to function properly with the adjacent parts. This furnishes a rational basis for a specification of one practical kind of elastic-limit, the stress that first causes a permanent set of an arbitrary value, such as 1 part in 10,000. Beyond this we may well recognize a yield-point, or yield-stress, at which the permanent set rapidly increases at an intolerable rate. An arbitrary definition might give this as the stress that causes the permanent deformation to pass the relative deformation by 0.005, or ½ of 1 per cent. Definitions such as these would have direct practical engineering application, would be fairly easy to use in testing and could be applied alike to all materials, ferrous or non-ferrous, whether heat-treated or not.

Our second interest in elastic-limits is in a field of the highest importance, which now for the first time is receiving a study that is detailed, accurate and broad; this is, the field of "fatigue failure." For ferrous metals, a large quantity of data on the investigation of fatigue has been obtained at the University of Illinois Engineering Experiment Station, through the cooperation of this station with the National Research Council, the Engineering Foundation and the General Electric Co. Many other sources have contributed information, and a grouping and a correlating of all the data and test methods are being carried out at the Bureau of Mines, by H. W. Gillette.

It is clear that for each steel, when it is clean and sound, of perfect surface smoothness and shaped carefully to avoid local overstresses, there is a limiting elastic-stress range that can be repeated a more or less indefinite number of times without the failure of the piece. If the repeated stress is the least bit too high the endurance of the steel, the number of stress repetitions for fracture becomes definitely finite; the repetitions become fewer as the stress becomes higher. The endurance curve, plotted as the logarithm of the stress against the logarithm of the number of cycles needed to break, consists of a straight or nearly straight line that comes down somewhat rapidly from the high stresses and small number of cycles to the elastic-stress and a cycle number somewhere in the region between 500,000 and 5,000,000; thence, the curve seems to be flat and of constant stress. But this is for the perfect piece. When the steel is not clean and sound, the whole curve is lowered and may become very erratic. When the surface is not

bottom of the splines. Of course, truly sharp corners and theoretically infinite stress do not occur; but the sharp cracks from excessive cooling-stresses in heat-treatment operations are very serious. Such cracks will cause an early fatigue failure if the part goes into service. On a single overload, a sharp corner will run the local stresses up beyond the yield-point; the yielding then rounds the corner and stops the further rise of the stress.

In practice, the weakening of a piece by a scratch or groove, by stressing in bending or in torsion, is a function not only of the ratio of the depth of the scratch to the radius at the bottom of it, but also of the ratio of the depth of the scratch to the thickness of the piece. A scratch or groove of given dimensions is relatively more serious the smaller the piece is. Endurance curves made on sheet metal, such as those of the recent McCook Field tests on sheet duralumin, must be affected greatly by the consideration of surface imperfections that are relatively large compared with the thickness of the piece. McCook Field has found that for duralumin sheet there is no fatigue elastic-limit stress, up to at least 500,000,000 cycles. It is possible that this finding is not inconsistent with the presence of a definite and reasonably high fatigue elastic-limit in forged duralumin connecting-rods. I write this paragraph largely to show our real lack of knowledge of the fatigue action of the light metals, knowledge that we need before we can go extensively into any complete substitution of light metals for steel in parts carrying transverse or torsional or long-column compression loading, and where the moment of inertia of the section is a large factor in the strength of the part. Extensive use of light metals is undoubtedly in prospect if the fatigue properties under the conditions both of casting and of forging are found to be satisfactory. Alloy-steels can match the light metals in the ratio of strength to weight for tension loading only.

What Engineers Design For

This brings us back to the question of what determines the choice of materials, and what, in general, are the conditions of design; that is, what we design for. I am not discussing costs. We inherited from our predecessors and our textbooks are filled with a scheme of design having strength as the controlling factor. The design for strength grew up in an age when the speed of moving parts was low, so that inertia forces were only of secondary, not primary, importance; and fatigue-failure was an improbable rather than an ever-present possibility. Even in that day the design of machine-tools, such as lathes and shaping, planing and milling machines, should have been based first on stiffness, and only secondarily on strength, for the first duty of a machine-tool is to hold the cutters rigidly in place with regard to the work.

In the automobile business we know, though we do not always practice what we know, that there are four coordinate bases of design, and from design, of choice of construction material. These four are strength, fatigue-resistance, stiffness and shock-resistance. In importance they may rank, for passenger-car design, as stiffness, fatigue-resistance, strength and shock-resistance. In truck work strength comes higher in the list. Design for shock-resistance in some respects is hardly within our province; it is not entirely reasonable that an automobile should be able to survive a collision with a stone wall. But it should be able to survive a clutch dropped into engagement on a "racing" engine, a case that conditions the strength and stiffness of every gear and shaft from the clutch to the rear wheels, for then the loadings, on

account of the acceleration forces of the rear wheels, are much higher than are needed to slip those wheels in more nearly normal operation.

An engine crankshaft furnishes a good example of the shift of the basis of design. At first it was strength, then fatigue; now, it is stiffness, to resist the torsional vibration. Each change of the basis of design brought an increase of the dimensions of the shaft compared with those of the cylinder-bore. And in this we do not practise as we preach, or as we know. For, in a general way, strength, against either single overloads or fatigue-failures, goes up with the tensile-strength of the material and the ratio of the moment of inertia to the diameter of the shaft, while the stiffness depends on the product of the modulus of elasticity of the material and the moment of inertia of the shaft. When we designed for strength alone we kept shaft diameters small and used nickel-chrome heat-treated steel for high strength and good hardness. When we design for stiffness, such a material is too good. A low-carbon steel would be just as stiff, for it has substantially the same modulus of elasticity; and, when the diameter is large enough for satisfactory stiffness, a case-hardened low-carbon steel would give adequate strength and hardness to the crankshaft and be cheaper and easier to forge, machine and heat-treat. But, lacking the courage of our convictions, we keep on using alloy-steel. So we could go through the parts of a car, examining everywhere the basis of design and the choice of materials. Steering-knuckles are controlled by fatigue-resistance, front axles by strength and shock-resistance, propeller and axle-shafting by strength and shock-resistance, gears by strength and wear-hardness, crankcases by stiffness, and so on.

The frame is very interesting. For a passenger car, the dominant property needed is stiffness, so that the frame and the body may agree with each other as the car runs. A partial realization of this is shown in the great deepening of the frames in recent years. For the most part, this deepening misses the point. It increases the bending stiffness that was never seriously bad anyway. The frame is nearly a two-dimensional rectangular part, loaded at the four corners by the springs and along the long edges by the body and the engine. Its defect of stiffness is against weaving or torsion, a twist of one end with regard to the other. Deepening of the side-rails does not make the frame torsionally stiff. We may find a way out by removing the cause of the weaving, by changing the spring loading to three points instead of four, by using transverse springing at one end of the car. If we stick to four-point springing we must meet the torsional forces with torsional rigidity of structure, which requires a structure in three dimensions instead of two. We might take a hint from the fuselage of an airplane, and make a permanent-top body a unit with the frame, making this unit simultaneously much stiffer and much lighter than the present structure of two parts quarreling with each other. The new "frameless" Lancia car shows a start in this direction. A mild low-carbon steel with be just as stiff as an alloy-steel; so that, as long as stiffness controls frame design, there will be nothing to gain from alloy-steel.

Factor of Safety

So long as design was based solely on strength, the old definition, "factor of safety equals the maximum strength divided by the working load," was all right. Then the argument was made that the yield-point, rather than the tension maximum load, should be used in calculation. This argument originated in the fact that the heat-treated carbon or alloy-steels have yield-points relatively much nearer to the maximum than the familiar 50 per cent relation of the normal carbon-steels. In fatigue research we find the fatigue elastic-limit to be substantially 50 per cent of the maximum strength in all worked steels, regardless of their analysis or heat-treatment. This seems to throw us back to the old scheme of using the maximum strength, rather than the yield-point, in computing the strength factor of safety. We should not forget that for long columns in compression, for I-beams or channels in bending or for tubing under torsion, the yield load is substantially the maximum load.

There are other factors of safety than that for strength to be considered, factors for deflection or rigidity, shock resistance, elastic-limit, break and the like. The numbers designating these factors of safety may be, and usually are, very different from the strength factors. Take resilience or shock-resistance as an example, in a steel with a yield-point of 50,000 lb. per sq. in.; maximum strength, 100,000 lb. per sq. in.; ductility, 30 per cent. Let the working-stress be 15,000 lb. per sq. in. Then the ratio of the strength factor of safety to the yield point is 3, to break is 6; the resilience factor to yield-point is $(50{,}000/15{,}000)^2 = 10$, and to break is about $20{,}000/4 = 5000$. The elastic work per cubic inch at working stress is $50{,}000^2/(2 \times 30{,}000{,}000) = 4$ in-lb.

Summarizing, the study of factor of safety brings up the same argument we have had before: The basis of design cannot be merely for strength. Hence, we cannot state a single factor of safety, but must have as many as there are bases of design; strength, fatigue, stiffness, shock.

THE DISCUSSION

Otto M. Burkhardt:—It is a problem to take a successful car of today and, without changing the design completely, to eliminate, let us say, 100, 200 or even 500 lb. of weight without imperiling the product in one way or another. The high-speed prime-mover is looked on as offering some solution. A precedent is furnished by the steam engine, with which we have noted that every time a new type of engine has been offered, the speed has been increased. The advantages of the high-speed engine are well known, and so are the disadvantages. There is much room for the exact analysis of stresses and deflections and, when the opportunity arrives, there will be modifications in favor of lighter weight.

John Miller:—What does Professor Upton think of the use of case-hardened steel for resisting fatigue? I have observed that case-hardened steel seldom breaks on account of fatigue-failure, and I have found that case-hardened alloy-steel will outlast plain alloy-steel in the Stanton repeated-impact test. In a passenger car or a motor truck, we sometimes get stresses as high as those in the Stanton test. In case-hardened steel we get a very high elastic-limit on the surface, where it is most needed, and there appears to be an absence of internal stresses; whereas, in high-carbon steel of the same hardness, the useful strength of the steel is reduced by the internal stresses.

Prof. G. B. Upton:—If not hardened above 400 Brinell, the fatigue elastic-limit should go up with the carbon content of a steel; and Mr. Miller's experience is in line with what we should expect for case-hardened stock under bending or twisting loads. I have had no experience in this case.

Mr. Miller:—I agree with Professor Upton that the light car is the coming car, and I believe that within the

diameter for an engine of this size. It would seem ridiculous to use chrome-nickel steel for a crankshaft approximately 3 in. in diameter, which apparently it must be to get rid of torsional vibration, when, with so large a diameter, plain carbon-steel will give a factor of safety that is greater than necessary. Often, in engineering development, we find it desirable to go back to something that has been abandoned. This applies also to the passenger-car underframe. If we must use a 9 to 10-in. channel to eliminate deflection, to get rid of body squeaks and the like, it is unnecessarily expensive to use chrome-nickel steel, because, with a frame of such depth, plain heat-treated carbon-steel will give as large a factor of safety as is necessary.

I think that the high-speed engine that Europe is adopting so extensively is not altogether a move in the right direction. This depends largely, of course, on the price of the car that is being built. I believe that a medium-speed engine is the best for a high-priced car, that the sensation of the excessive speed of rotation that can be felt in the high-speed engine will be condemned by the wealthy buyer, and that he will demand that his car be equipped with a medium or even slow-speed engine.

PROFESSOR UPTON:—The high-speed engine ultimately will not be the most popular. In Europe, engines are taxed according to the bore and, consequently, are being reduced in size and the speed is being increased. Some day, when the method of taxation is changed, the design of engines also will change. The speed at which lubrication is safe will limit the high-speed engine. Mechanical efficiency is higher in the medium-speed engine than in the high-speed engine. In the latter the inertia forces vary with the square of the speed and become large in comparison with the useful loads. The highest mechanical efficiency in both the high and the medium-speed engines will be found to be at about 1500 or 1600 r.p.m.

JOHN C. TALCOTT:—Professor Upton recommends the use of carbon-steel for frames. I believe that a frame can be built lighter with alloy-steel than with plain carbon-steel. It can be braced so that it will be stronger than a straight carbon-steel frame. I have seen straight carbon-steel frames break on trucks. If an alloy-steel frame gives trouble, it is better to add 10 lb. in braces than 60 lb. in the side-members.

PROFESSOR UPTON:—What I had in mind in recommending a return to carbon-steel frames was that the frames are being made deeper. We have not gone very far into this problem. Body weaving, however, is not due to the whole frame, but to one side being moved round. The reason is that we have not designed the whole thing so that it will be free from twisting. Twisting might not be objectionable in a truck frame, but on passenger cars it is objectionable. Daimler, in England, mounts the body in such a manner that it does not touch the frame, except at four points. It is fastened at the forward end by two hinges and at the rear by two rubber bumpers. This arrangement lets the body work on the frame. The forward end is flexible on the hinges, and they do not have to make the frame stiff; they make the body stiff and let it work on the frame.

MR. BURKHARDT:—Trusses usually localize stresses. They do not do anything else than brace up a weak point. In railroad cars, they can be of a certain design, but in the automobile the complications are greater and the best locations for them are rather doubtful.

(*Concluded on p.* 312)

Single-Valve Internal-Combustion Engine Design and Operation

By R. Abell[1]

New England Section Paper *Illustrated with* Photographs and Drawings

SPECIFICATION is made of 13 essential factors that the author believes are necessary for attaining better engine performance; he then describes how improved results have been obtained by the use of a single-valve mechanism on an engine having an unusually high compression-ratio and using ordinary gasoline as fuel.

The latest type of engine built with the single-valve mechanism is illustrated, and detailed descriptions of its development, design and operation are given, together with comments upon its factors of advantage and data obtained from tests.

In designing this single-valve mechanism, the primary object was to solve the problem of positively closing poppet-valves without using springs and thus to produce a type of engine that would operate efficiently at greater speeds than are possible with spring-closed valves. Another object was to reduce the temperature of the exhaust-valve. The author claims that the design under consideration overcame disadvantages, such as carbon deposit, regrinding of the valves, overheating and detonation, and permits an increased compression-pressure and a consequent gain in power and efficiency.

IN the past few years a great amount of scientific investigation has been made on gas engines in the United States and in Europe. Problems have been solved that fill the gaps in engineering data to such an extent that we can discuss engines now on a more definite basis. Ricardo has given us some definite values of the increased efficiency obtained when using the higher compression-ratios that are permitted when additional exhaust gas is used in the fuel mixture. The Midgley indicator has set before us graphically the causes of detonation and has shown how some "doped" fuels help to eliminate detonation in an ordinary engine. During the last year, several very interesting laboratory tests have been run on engines operating with unusually high compression-pressure which showed great gains both in power and economy. Fuel-consumption values as low as those of Diesel engines have been obtained when using the ordinary four-stroke-cycle principle. One of these tests was run with 500-lb. per sq. in. compression-pressure with benzol as the fuel and resulted in an indicated mean-effective pressure of 176 lb. per sq. in. Another test made with ordinary fuel under a 120-lb. per sq. in. compression-pressure resulted in a 25-per cent increase of power over that obtained with its normal compression-pressure of about 80 lb. per sq. in. In the first case, results were obtained with a special fuel; in the second, they were attained by using special laboratory equipment by which the temperature of both the cooling-water and the intake gases could be controlled accurately. These tests are of value inasmuch as they set a high mark for engineers to shoot at, but appear to be of not more than academic interest to the automotive industry for the reason that neither method is commercially practicable. Recent investigations have shown that the key to the situation is the finding of practical means to reduce the temperature of the combustion-chamber surfaces, especially that of the exhaust-valve, which is the hottest part of the chamber in all engines.

The extreme heat of the exhaust-valve often has been stated to be one of the sources of detonation, but no definite value has been placed on it as a trouble maker because no method of segregating its influence on detonation from the other contributing elements has been known. Having built engines both with and without hot valves, I can state definitely that the relatively high temperature of the exhaust-valve is the chief cause of detonation.

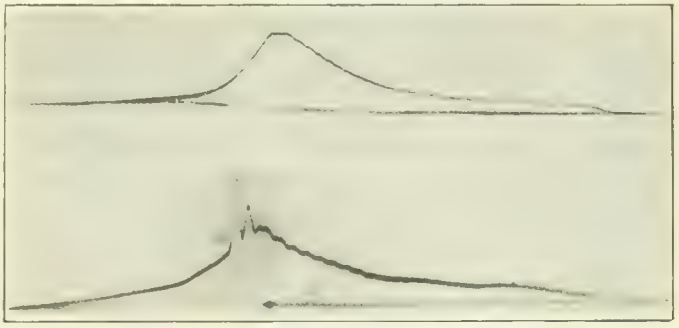


Fig. 1—Two Indicator-Cards, the Top One Showing a Normal Combustion and That Underneath One in Which Detonation Occurred

Fig. 1 shows two Midgley indicator-charts, the upper one being characteristic of an engine operating normally. While the pressure line shows very faint irregularities, it is substantially a smooth curve. The dark spots indicate the beginning of detonation. A slight variation will always be seen in the smooth lines before the knock is audible. The lower chart is a good illustration of the way a curve will vary with detonation. In this case the pressure drop is nearly 50 per cent of the maximum on the first fluctuation.

Fig. 2 shows a chart made by Harry R. Ricardo, of London, that is especially valuable since it shows the very great advantage of high compression, provided detonation can be eliminated. The upper branch of the upper curve shows the gain in power from high compression, using exhaust gas to prevent detonation. The lower branch of this curve is what occurred with the same engine under the same conditions without the addition of exhaust gas. Detonation is characteristic at a compression-ratio of about 4.7 to 1. The lower curves show the fuel consumption as applied to the two upper curves. At a compression-ratio of 7.5 to 1, without the exhaust gas, the fuel consumption came back to 5.5 lb. per hp-hr.;

[1] M.S.A.E.—General manager, Single Valve Engine Co., Mattapan, Mass.

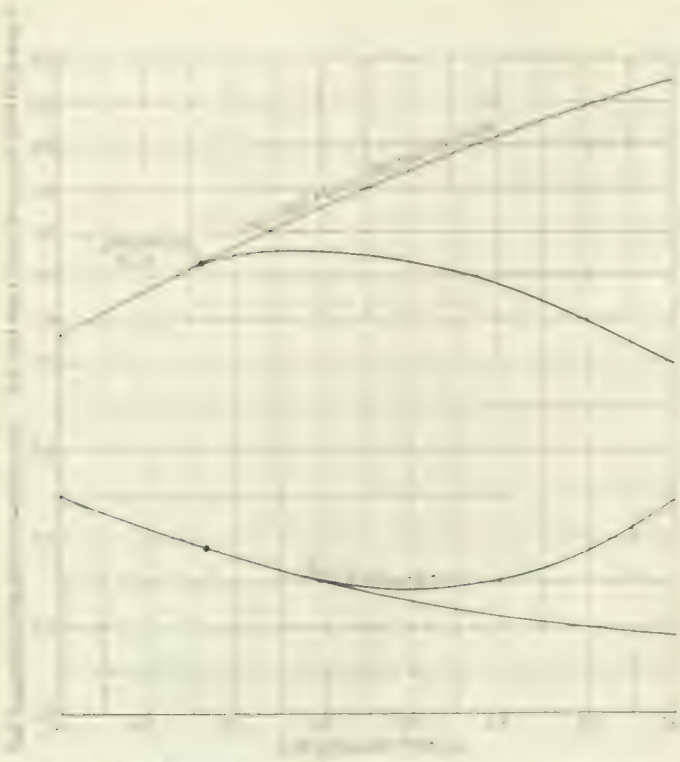


Fig. [illegible] Curves Showing the Advantage of High Compression If Detonation Can Be Eliminated

The Upper Branch of the Upper Curve and the Lower Branch of the Lower Curve Show the Results Obtained by Using Additional [illegible] to Prevent Detonation, While the Inner Branches of Both Curves Were Secured Without the Use of Exhaust Gas

with the exhaust gas added to the mixture the fuel-consumption curve dropped to 0.4 lb. per hp-hr. I call attention to the fact that this chart was obtained from a test made on an engine having hot valves, and it appears to be the most logical solution of eliminating detonation in an ordinary engine operating under high compression. I include it as a basis for a comparison to be made later.

So far as I know, the gas engine is the only piece of mechanism that operates with any of its vital parts at a red heat; and, irrespective of the improvements in valve materials that permit a fair amount of durability when operating at high temperatures, a gradual deterioration and a loss of power that call for expensive overhauling occur. This intense heat is the principal obstacle standing in the way of obtaining commercially the results that all engine designers are striving for, namely, higher efficiency and greater durability.

Essential Engine-Performance Factors

The essential factors necessary for better engine performance are:

(1) Higher [illegible]
(2) A lower maximum temperature of the combustion-chamber and the valves
(3) A greater valve capacity
(4) Positive valve action at all engine speeds
(5) A compact combustion-chamber without pockets
(6) Means for vaporizing the fuel completely
(7) Uniform fuel distribution
(8) Adequate ignition
(9) A central location of the spark-plugs
(10) Light reciprocating parts
(11) A rigid crankshaft
(12) Efficient cooling and lubricating systems
(13) Silent operation

The particular type of engine shown in Fig. 3 is one of four sizes that have been built to date, this being the last. In this case, the fan is mounted on the front end of the camshaft, but it was never used. The lower part of the engine, up to the head, was purchased from a firm in Newark, N. J., that has built some highly efficient engines having overhead shafts but with the standard two-valve arrangement. The part I supplied for this engine is from the cylinder block up.

Several important things are illustrated in Fig. 3. First, the aluminum manifold is of the simplest design, being merely a flaring elbow with a partition coming down about half-way around the elbow to prevent surging of the mixture to some degree. The exhaust-manifold is also of aluminum. The spark-plugs are set at an angle of 15 deg. The end of the screw-plug evident at the rear end is for closing the hole in which the rotary distributor operates. In demonstrating the effect of temperature of the distributor, we remove that plug when the switch is thrown off and pull it out by hand. It is warm, of course, but it can be held in the hands when wearing cotton gloves. The manifold is only half of a circle in cross-section, the other half of it being in the head. It is a plain milling operation to run across the head and mill off the surface to which the manifold is bolted.

On this engine the accessory drives are transverse at the front, and Fig. 3 shows also where the generator is mounted. The other side of the engine exactly balances the side illustrated in Fig. 3 with similar mountings for the water-pump and the ignition apparatus. The starting motor is in the bell housing; it has a standard S. A. E. mounting. Two buttons are provided to facilitate lifting the aluminum cover. The center one is a hand nut and is the only means of holding the cover down. Only about 15 sec. is required to lift the cover and no tools are needed.

Fig. 4 shows two sections of this engine. The crankshaft is made from a solid billet and has main bearings of 2½-in. diameter. This shaft is a remarkable example of good balance at any speed. Partly on account of the large diameter of the bearings and partly on account

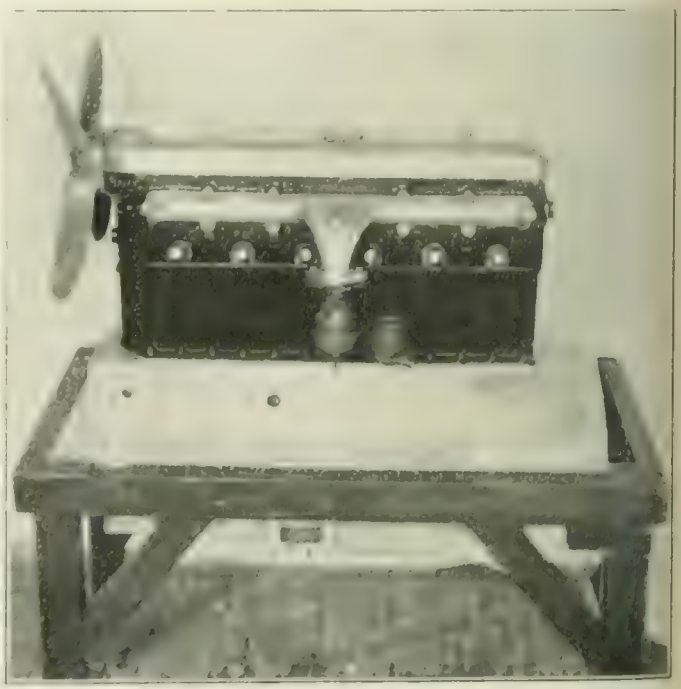


Fig. 3—Exterior View of the Single-Valve Engine, Showing the Simple Design of the Intake Manifold and Clean External Appearance

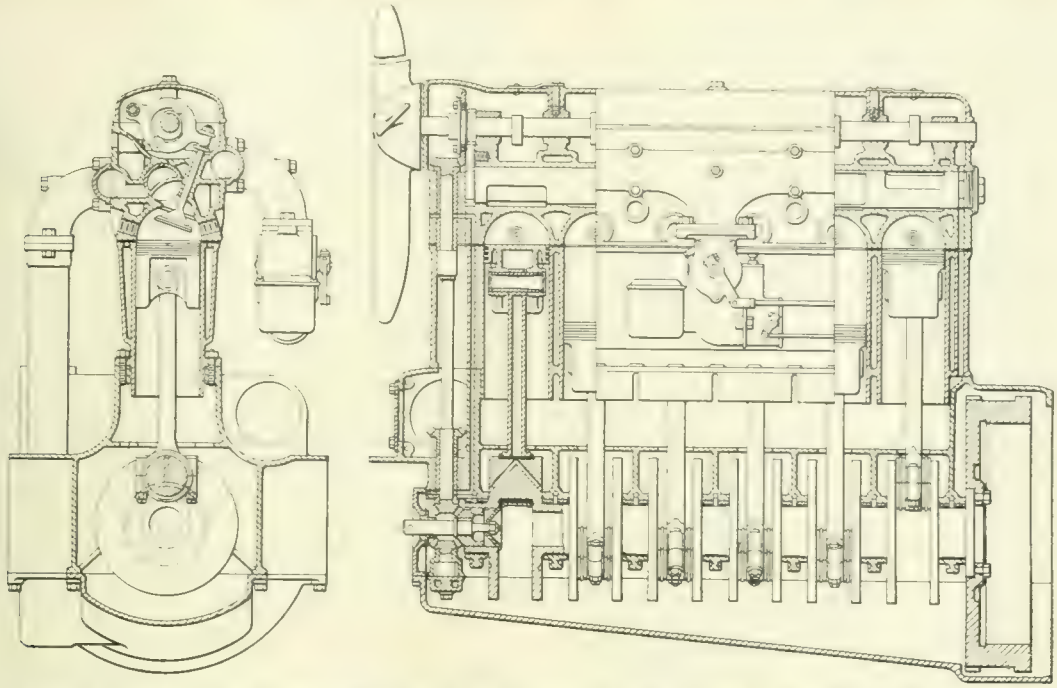


FIG. 4—END AND SIDE ELEVATIONS, PARTLY IN SECTION, SHOWING THE POSITIVELY OPERATED POPPET-VALVE AND THE ROTARY DISTRIBUTOR VALVE

of the light connecting-rods and the light pistons, the engine is practically free from vibration. The 10-in. rods weigh only 1½ lb. complete. The piston, with its rings and pins, weighs 1 lb. In this case, the Ricardo type of piston was used; it performed very satisfactorily and stood up well. The thickness of the piston-head is about 1¼ in.; the walls are about ⅛ in. thick below the ring grooves and 3/32 in. thick at the lower end. This is not a split type.

Regarding the construction of the cylinder block and the crankcase, the parting line comes at the top of the bell housing and a little higher than on the average job. The principal reason for this is to get the cylinder barrels to project into the crankcase to serve as oil traps. The main-bearing supports are webbed and form baffles over the crank discs. This prevents excessive oil being driven into the cylinder; such oil as does get by is trapped again in the case. The result is that, even though the oil is maintained at a high level so that the discs actually dip, it is impossible to make the engine smoke. This is due to the combination of the two baffles.

In regard to the head, the combustion-chamber is a true hemisphere. The valves are set on a slight angle to balance the design. This permits the camshaft to be maintained on the center line and also results in a more accessible valve mechanism that can be withdrawn from the head, from the side shown, without interference. The distributor, which is of very simple construction, is placed very close to the valve. The pocket which is formed by the distributor in connection with the valve, is regulated by its distance from the valve-seat. In this case the volume is 12 per cent of the piston displacement, which is 41 cu. in. per cylinder. The manifolds are in duplicate, one somewhat above the other. Except for a lack of accessibility, the vertical shaft-drive, which is mounted in bronze bushings at the top and at the bottom, was perfectly satisfactory. The oil-pump is bolted to the lower part of the crankcase and is of an ordinary gear type but it has no oil-pipe connection. It is bolted on to the bottom and the intake and the delivery ports are drilled in the crankcase and connected with steel tubes so that the pump can be taken off for inspection.

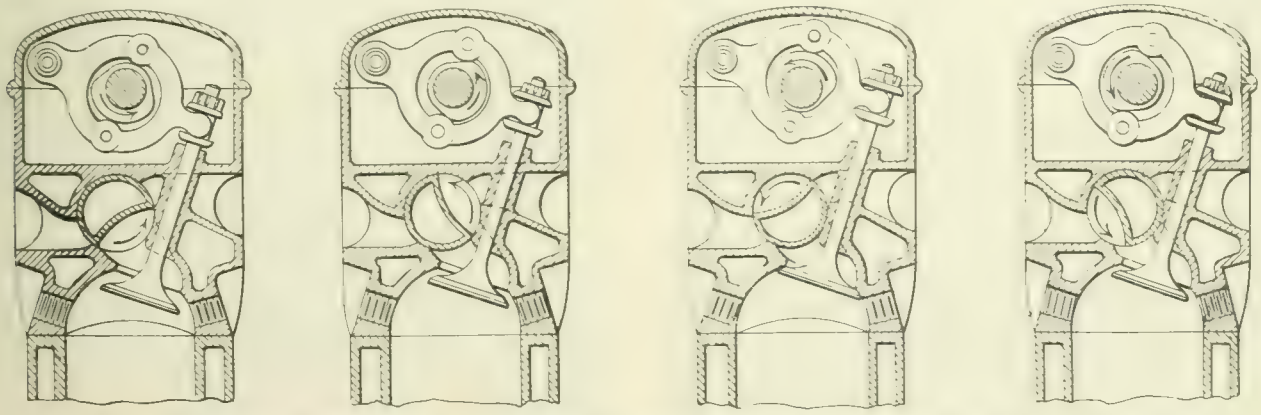
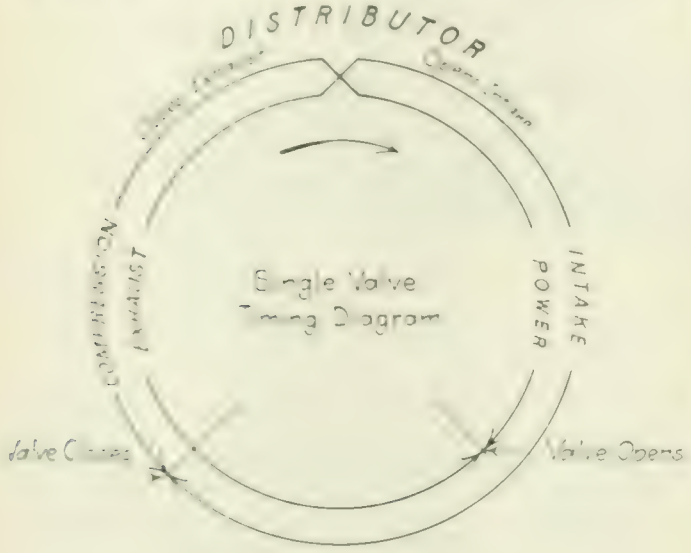


FIG. 5—FOUR SECTIONAL VIEWS SHOWING THE RELATIVE POSITIONS OF THE DISTRIBUTOR VALVE DURING THE CYCLE

From Left to Right They Show the Piston at the Top Center and the Exhaust-Valve Closed and the Intake Opening; the Piston at the Bottom Center with the Intake-Valve Closing; the Piston at the Top Center or the Beginning of the Power Stroke; and the Piston at the Bottom Center with the Exhaust-Valve Open

The four sections shown in Fig. 5 are duplicates of the sections illustrated in Fig. 4 but are presented to illustrate the position of the distributor in regard to the top and the bottom centers of the cycle. Fig. 5 also



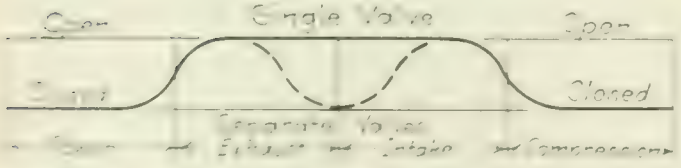


Fig. 5—Timing Diagram of the Single-Valve Engine (Above) and Sectional Views Showing Action of Single and Double Valves

shows the relative position of the valve. In the extreme left-hand view the piston is at the top center; the valve is wide open and the cam is in contact with the roller in the middle of the dwell period or pause of the valve. The distributor which runs counter-clockwise has just closed and the exhaust port is about to open the intake. In the next view to the right the piston is at the bottom center. The valve is exactly half-closed. The distributor is about half-shut or possibly slightly less than half-shut to the intake. The cam in this case is engaging the top and the bottom roller symmetrically.

In the right central view of Fig. 5, the pistol is on the crank quarter and is beginning the power stroke. The valve is closed and the cam is diametrically opposite to the first position. The distributor rotates at camshaft speed; both ports are closed, and it is merely going through its idle period. In the extreme right-hand view the piston is at the bottom center and at the end of its power stroke. Connection is established to the exhaust port. The cam is opposite to the position assumed in the view to the left of the center. It should be noticed that the valve is comparatively large in diameter and has a port opening of $1\frac{1}{4}$ in.; it could be larger. The cam, shown opened the valve 7 16 in.; it could be made to open the valve more if this were of any advantage. The two spark-plugs point toward the center of the combustion-chamber and are as close to the bottom of the combustion-chamber as it is practicable to have them.

The upper diagram in Fig. 6 has reference to the top-center position. The exhaust-valve opens at the usual period, the average timing being 45 deg. from the bottom center, and continues open until the usual exhaust-closing period. At this point the distributor performs its function; it closes the exhaust and opens the intake. The lower diagram illustrates the difference in the mechanical action of the present two-valve engine from that of the single-valve engine. Assume that the two engines start to open at the same time. The single-valve engine attains its full-open position at the same time as does the two-valve engine and it remains open; whereas, in the two-valve engine the exhaust-valve immediately closes, its intake opens and joins in with the other line and completes the cycle. The cycle of the single-valve engine is identical with that of standard practice.

Operation

The mechanism consists of one poppet-valve per cylinder and each valve is opened at the usual exhaust-valve opening-point; it remains open throughout the exhaust and intake periods and is positively closed at the usual intake closing-point. Each valve is supplemented by a rotary distributor, running at camshaft speed, which controls the flow of intake and exhaust gases to and from their respective manifolds.

To solve the problem of positively closing poppet-valves without using springs, and thus to produce a type of engine that would operate efficiently at greater speeds than are possible with spring-closed valves, was the primary object of designing this mechanism. Another object was to reduce the temperature of the exhaust-valve. The problem was solved, but several other advantages were discovered during the course of development. These advantages overcame many of the difficulties and the limitations that the engine designers and the public have had to contend with, such as carbon deposits, regrinding of the valves, overheating and knocking. At the same time, the design permits an increased compression and consequent gain in power and efficiency.

In the ordinary poppet-valve engine separate valves are provided for the intake and the exhaust gases. The intake-valve is maintained at a comparatively low temperature at all times by the incoming gas, but the exhaust-valve reaches a maximum temperature of more than 1200 deg. fahr. This is a red heat and is much too hot to permit using a compression-pressure value that will obtain the best results in the development of power, the fuel consumption and durability of the valves. An extreme range of temperature of the combustion-chamber exists in all engines to date. The compression-pressure of automobile engines ranges between 60 and 80 lb. per sq. in. gage pressure, or a maximum compression-ratio of 4.5 to 1. Scientific tests by Ricardo and others have shown a gain in power with ordinary fuel up to a compression ratio of 7.5 to 1, by using some means to eliminate detonation. In this case the gain was 18.7 per cent. The tests showed practically no connection between detonation and the temperature of compression.

Incandescent spark-plug points are often a contribut-

ing cause of detonation in combination with hot valves, but this difficulty has not been found in the development of single-valve engines having a compression ratio of 6.5 to 1, which has been employed with perfect success in six-cylinder engines used in a standard car on the road. It has been impossible to make this engine knock during 8000 miles of road test, even when the engine was stalled by using the brakes with the throttle wide-open.

Development History

Fig. 7 illustrates the first application of the single-valve mechanism to a water-cooled automobile-engine. A single-valve head was adapted to fit a Chevrolet engine; all of the lower parts of the engine were retained in their original form. Some difficulties were experienced in providing a drive for the overhead camshaft, but a compromise was made by using the water-pump shaft and running two drive-chains up overhead. In this case the valves were mounted vertically in the center of the combustion-chamber, which was not exactly hemispherical; the corners of the combustion-chamber were at an angle of 45 deg. The reason the combustion-chamber was not made to be a true hemisphere is that I did not appreciate the real value of the hemispherical form at that time. The distributor is made in two sections in this case, with a tongue connection merely as a convenience for the foundry in making the core which would be apt to sag if made in one piece and would be troublesome to handle. Helical spur-gears drive the distributor from the camshaft in this case.

When the dotted power-curve in Fig. 8 was taken, it was with an engine that was accurately fitted and that had been limbered-up; it was the best curve obtainable up to that time from that engine. When the new head was made, it was fitted to a new engine and was set-up so tight that when we put the engine on the dynamometer to determine the friction load, we found that 7 hp. was required to jack it over at 1000 r.p.m. With the former engine only 3 hp. was necessary to jack it over at the same speed; so, there was a handicap of 4 hp. at 1000 r.p.m.

In the application of this single-valve principle to the Chevrolet engine, only standard parts were used with

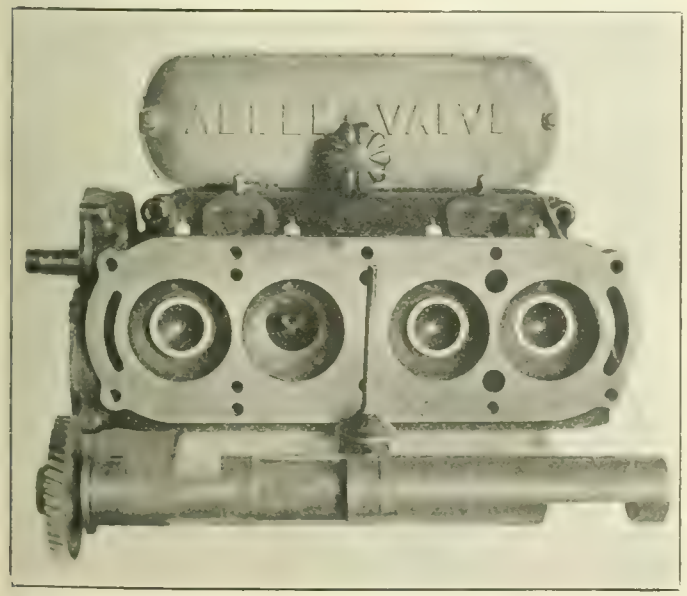


Fig. 7—The First Application of the Single-Valve Mechanism to a Water-Cooled Automobile-Engine

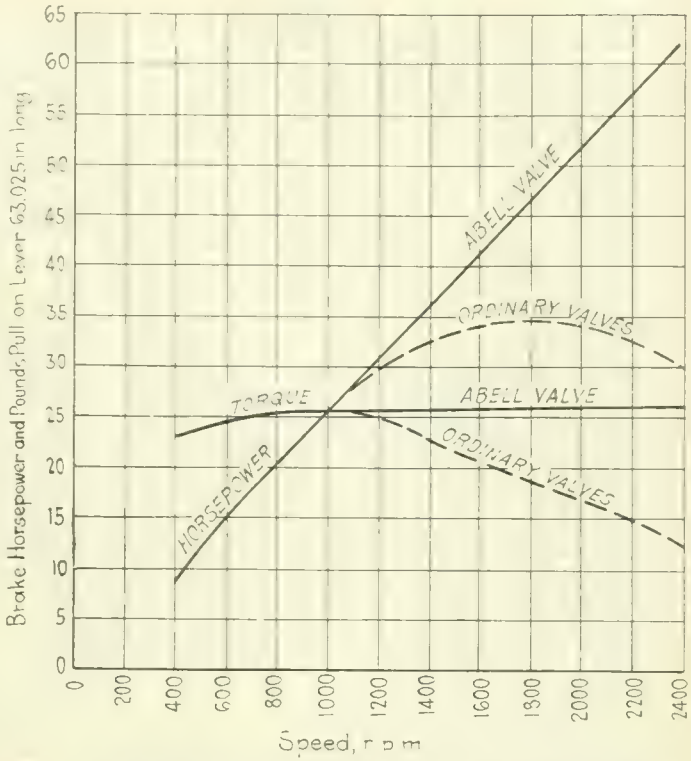


Fig. 8—Results of a Dynamometer Test of the Single-Valve and the Conventional Cylinder-Head

the exception of the cylinder-head and the valve mechanism. The compression pressure used on this engine was about 115 lb. per sq. in. gage. At a speed of 2000 r.p.m., the engine with the two-valve head developed 34 hp., but with the single-valve head it developed 51 hp., an increase of 50 per cent. At a speed of 2400 r.p.m., the original engine dropped to 30 hp. but, with the single-valve mechanism, it climbed to 62 hp. This was the highest speed at which the dynamometer tests were made, owing to severe crankshaft vibration resulting from using a crankshaft that was too small in diameter to carry the increased power safely. The power curve with the single-valve mechanism was a straight line and showed a slightly increasing torque.

An application of the single-valve mechanism was then made to a 3½ x 5-in. six-cylinder Trego engine of 288 cu. in. displacement. The first test of the engine at 2000 r.p.m. on a dynamometer showed 64 hp. with a compression pressure of 80 lb. per sq. in. The construction of the engine to which the head was adapted would not permit the increasing of the compression pressure without making a considerable change, but we did gain a decided increase in power over the best obtained with the original valves.

The fourth engine equipped is shown in Fig. 3. This is a 3¼ x 5-in. engine of 249-cu. in. displacement having a 115-lb. per sq. in. gage compression-pressure. This engine was mounted in a standard Roamer car and given road tests of 8000 miles, throughout which it showed unusual performance. Soon after this car was put into commission, a hill-climbing test was made by a car builder, who tested this engine against his standard make of six-cylinder engine in a car that was showing good average road-performance. A comparison was made between the two cars, taking into consideration the size of the engines, the weight of the cars, the size of the wheels and the rear-axle gear-ratios. These figures gave the manufacturer's car an advantage of 12 per cent.

mile, which is only a moderate speed for this engine. In other words, a much smaller engine geared to turn about [illegible] revolutions per mile would give a better performance than the average on acceleration, at least 70 m.p.h. at top speed, and a greater fuel- (per gal.) mileage.

Fuel Consumption

Regarding fuel consumption, the test car, which weighed with a passenger about 4000 lb., showed about 25 miles per gal., or approximately 50 ton-miles per gal. of gasoline, which is above the average. On a fuel test at speed on one of the long concrete roads in Michigan where a maximum speed of more than 70 m.p.h. was reached several times, the fuel consumption was 21 miles per gal. No outside heating arrangement was used for the intake, and little need for it was found. This is accounted for by the fact that the unvaporized particles of fuel in the intake-manifold are warmed-up by contact with the distributor and the poppet-valve which, in turn, is thereby maintained at a practically constant temperature of 600 deg. fahr. The incoming gas is also warmed by the absorption of the small amount of exhaust gas that is left in the port between the distributor and the valve, and this is a decided help in completing vaporization. Moisture heat applied directly above the carburetor would increase the fuel mileage in cold weather.

Ricardo states that, for every 1 per cent of exhaust gas added, the *flame temperature* is lowered 45 deg. fahr. Thus, with the 12 per cent in the distributor and in the pocket, the flame temperature is lowered to a considerable degree. All this, coupled with the fact that the hemispherical combustion-chamber is conducive to more complete combustion than is possible with other forms, results in less heat being reqired in the manifold. Another way to explain this function is to say that it is the incoming gas that prevents the excessive heating of the poppet-valve, and that this excess heat, being transferred to the incoming charge, does useful work and results in a local hot-spot for each cylinder at the most effective point, accomplishing the desired result without the usual hot-spot. This heat transfer is especially valuable for the cold engine, because some of the heat from the exhaust of the very first explosion is picked up by the incoming charge and results in normal operation in a very few seconds even in cold weather. It is not necessary to enrich the mixture until the entire engine has become heated to its normal point. The effect is similar to that of the fuelizer and is accomplished automatically without using an extra volume of fuel but is the product of factors inherent with the single-valve design and so requires no additional mechanism. Popping back through the carbureter is practically eliminated.

Separate-Valve Difficulties

Some of the difficulties met with in an engine having separate valves for the intake and for the exhaust are: first, that the temperature surrounding the exhaust-valve seat is so high that water adjacent to these surfaces boils and causes an increased temperature of the cooling water. This, in turn, requires a larger radiator and a more efficient cooling system than is needed in the single-valve type; second, when two or more ports enter the combustion-chamber, they occupy space that otherwise would be available for cooling surface. With the single-valve, only one port enters the combustion-chamber and there is not only an entire absence of boiling water near the valve seat, but about 25 per cent more of the outer surface of the combustion-chamber is available for cooling. With an undersized radiator and no fan, the test car was driven through the mountains of western Pennsylvania in hot summer weather with no sign of overheating. In fact, the motometer did not rise to the normal mark on the longest climbs of 2500 ft. above sea level.

Combustion-Chamber Form

In the single-valve engine the combustion-chamber is a true hemisphere with a machined surface. This form of combustion-chamber, which is permitted by the use of a single valve, is a decided factor of advantage. At the end of 8000 miles, the machined surface was turned to a straw color and the head of the valve was blued by the heat. These colors indicate that the maximum temperature of the wall of the combustion-chamber and that of the valve did not exceed 500 deg. fahr. and, as a result of this comparatively low maximum temperature of the valve, no warping or pitting of the valve or of its seat occurred. Hence, the necessity of frequent regrinding of the valves is eliminated.

In contrast to this, it is interesting to note that no aviation engines having as high as a 6 to 1 compression-ratio are in common use, and all engines using a compression ratio of 5 to 1 or higher have great difficulty due to the warping or pitting of the exhaust-valves and their seats even when special alloy-steels are used. This

necessitates frequent replacements and labor or expense to keep them running satisfactorily. Of course, the use of higher compression would result in a greater amount of horsepower if it were not for the fact that the charge would detonate badly because of the hot exhaust-valve. When the valve is kept below the temperature that causes warping and pitting, it is no longer a contributing cause of detonation.

In Fig. 9 the diagrams reproduced further illustrate the points I have mentioned in relation to combustion-chambers. At the left is a typical diagram of a two-valve engine. The valve is in the head and is obviously at a disadvantage with the other diagrams so far as carbon deposits are concerned, because the gases follow different paths in entering and in leaving the cylinder and the walls of the combustion-chamber are not being swept evenly by those gases. While the gases will follow a streamline, the corners form dead pockets; the reverse would be true when the other valve functioned. I believe that the middle diagram of Fig. 9 illustrates a better combustion-chamber than any now being used, but this one was defective, as we found it. After two weeks of running on the dynamometer the head was removed and we found carbon deposited in the corners where the trouble had started. The true hemispherical form of combustion chamber is shown in the diagram at the right in Fig. 9. When gas enters from the valve, it must of necessity sweep those walls uniformly and, on leaving the cylinder during the exhaust stroke, it must sweep them again. So, the flow of gas has a great influence in keeping the oil-film in constant motion and does not permit it to come to rest for a long enough period to burn-on any carbon.

For the first time the practical use of the hemispherical combustion-chamber is available in combination with the single-valve arrangement, because the port area is not limited, as is the case with separate valves. The single valve can be three-fifths the diameter of the cylinder, which is a greater area than it is possible to obtain even with four valves per cylinder as used on some aviation and racing-car engines. Not only can a larger single-valve be used in a given-sized cylinder, but it can be opened farther because its closing is positive instead of being dependent on the limited speed of springs.

To finish the hemispherical combustion-chamber in one operation is a very simple machining operation, and it has been discovered that this type of chamber, in connection with the single valve, prevents the accumulation of carbon deposits even though the engine is run with an over-rich mixture or with a piston that pumps oil. The reason for this is found to be that the gases passing in and out of the combustion-chamber through the same path keep the oil film in constant motion and, as no pockets are provided for the oil to lodge in out of the streamline of the gases, it cannot come to rest for a long enough period to carbonize, especially when the temperature of these walls is maintained at such a comparatively low point. These features make it evident that the outstanding advantage of a single-valve engine is a thermal one and that the lower temperature of the combustion-chamber walls eliminates the difficulties encountered in the past and permits the use of much higher compressions.

Mechanical Features

In considering the mechanical features of this design, I refer first to the distributor, which is a single revolving element made of cast iron and cored-out to save weight. For the average engine the diameter is about 2 in., and an ordinary running clearance of from 0.003 to 0.005 in. is used. From the beginning absolutely no difficulty due to sticking has been experienced; the distributor does not get hot enough to distort or to burn-off the oil-film that is picked up from the gases and is always present. The distributor controls the flow of both the hot and the cold gases and a moderate temperature is consequently maintained, never becoming high enough to color the metal even to a shade of light straw. The distributor should not be confused with a rotary valve, as such, for the very obvious reason that it does not hold either the compression or the explosion pressure nor does it come into contact with the gas during combustion. The poppet-valve holds the compression and the explosion pressures and thereby shields the distributor from any pressure except that in the manifolds, which is comparatively low. For this reason, the oil-film on the distributor is sufficient to seal it effectively and the engine idles as well as any other. The test car could be throttled down to less than 3 m.p.h., and it accelerated rapidly without any sign of loading.

Manifold Design

One-half of each of the intake and the exhaust-manifolds is cast into the head. This is done for the following reasons:

(1) Such a construction makes a much simpler job for the foundry, because the cores are supported the entire length of the head and act as gas vents

(2) The casting can be inspected better for imperfections, since it is possible to look straight through the ports from one side to the other

(3) If desired, the intake-manifold can be polished on the inside

(4) A very compact arrangement is secured; the manifolds project less than half the usual distance

(5) One-half of the intake-manifold is heated by the water-jacket to a desirable temperature and, on the other hand, one-half of the exhaust-manifold is cooled to a desired temperature so that the difference in the amount of heat escaping under the hood is considerable

(6) About 30 per cent less water-cooling system is required than with other engines of equal size

(7) Aluminum exhaust-manifolds can be used without danger of melting

The sectional view shown in Fig. 10 is included for reference with regard to manifold and other design features. I focused my attention on the positive operation of the valve and drew charts to determine what kind of cam would be required to eliminate lost motion.

The fulcrum point for the rocker-arm is integral with the bearing cap which must, of necessity, fit the camshaft. In this case the rollers have a 3/4-in. outside diameter and each has a 7/16-in. hole. They revolve on hardened bushings having 5/16-in. holes. An ordinary cap-screw is used to hold the bearing cap in place. If, after a long enough time, the distance between the rollers is enough to cause noise, we simply pull the bolt out, remove the top rollers and replace them with others that are over-size. The connection to the valve-stem is merely a rounded end; it would be made by a stamping process and ground to size. The collar is an integral part with a castellated head and is a simple machining job. It has been suggested that this collar be

made in one piece or more adjustable so that the wear can be taken up. I have made such a collar, but it is not practicable because a compound adjustment is required on a small part that is not worthwhile. If it wears out, a few cents will buy a new one, so it is not worthwhile to make it complicated.

Positive Valve-control Mechanism

Of all the mechanical features of this engine the most interesting is the mechanism for positively controlling the action of the upper-valve. This valve opens with exhaust-opening and closes with intake-closing timing so that the cam shape is very different from that used with separate valves. The cam operates a rocker-arm having two opposed rollers, one of which acts for opening and the other for closing the valve. For proper timing of the valve, the cam is of such a form that it is in contact with both rollers in all its positions.

The rocker-arm is of such a length that its angular motion is relatively small and the valve opens twice the distance of the cam-action throw. With a valve opening 7/16 in. the lever moves only 3 deg. on either side of its central position and produces the minimum side-thrust on the valve-stem. Thus, the simplest possible mechanism fills the requirements.

The cam shown in Fig. 10 opens the valve 45 deg. before the bottom center and stays open; the distributor shifts the manifolds at the top center and the cam closes the valve at 45 deg. after the bottom center on the compression stroke. Thus, the valve opens but once for each power impulse.

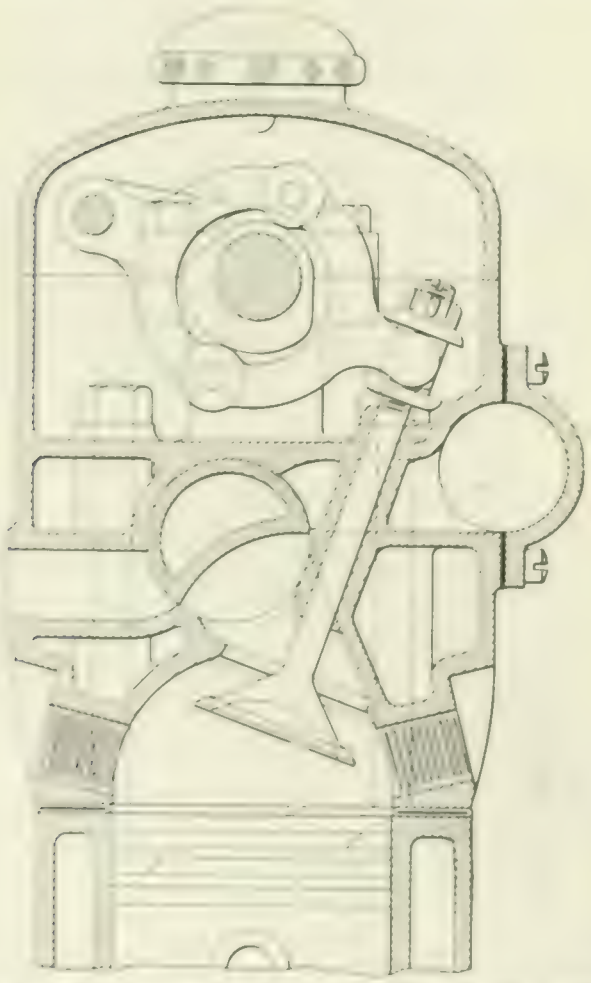


Fig. 10—Cross-section through One Cylinder Head of a Single-Valve Engine

Another important detail is the difference in the rate of acceleration and deceleration of the valve in opening and closing. The valve leaves the seat at about four times the speed with which it approaches the latter in closing. This is desirable for power and for silent operation. The variation in the speed of the valve is due to the relation of the angular motion of the rocker-arm to the direction of rotation of the camshaft. This action corresponds to that of a cam having a carefully designed ramp but, in this design, it is accomplished by the combination of the arrangement of the rollers on the rocker-arm and the direction of rotation of the camshaft. The valve action is unusually silent and the valves do not chatter at full speed as is the case with a spring-closed valve.

Valve Adjustment and Gearing

The adjustment of the valve is by the grooved collar threaded to the valve-stem and provided with a castellated head for a cotter-pin. In adjusting the valve the proper procedure is to draw the valve to the seat, back it off one notch and then insert the cotter-pin. It is not necessary to hold the valve against its seat mechanically. About one-half the usual amount of tappet clearance is used. This system cannot be used with separate valves, as the exhaust-valve would be drawn from its seat during the suction stroke. The valve is constantly turning in relation to the valve-seat, since there is no spring to restrict it.

This type of engine requires a vertical-shaft drive for the overhead camshaft, and I have found it satisfactory in every way. The usual gear-noise is not present, because there is no reversal of torque in the shaft due to the absence of valve-springs and also to the fact that there is but one-half the number of valves to operate, which reduces the load on the shaft to less than one-half that which is present in other engines.

Two advantages of using gears for the overhead drive are (a) that they are about one-half the diameter required in the present standard types and so the tooth speed is correspondingly less and (b) that they can be adjusted accurately for meshing properly, which is not possible with gears on parallel shafts that have fixed centers. The cost of the four small gears does not exceed that of the usual two large ones. It is universal practice to use the overhead camshaft on aviation and racing-car engines; many of the later European passenger-cars and a few cars that are built in the United States, are using it successfully, also. I predict that the overhead camshaft will become the standard method in the future because of the increased efficiency and accessibility that it provides.

One very great advantage of the overhead-camshaft design is the extreme accessibility. Because the entire valve mechanism is uppermost, close adjustment can be made with little effort and no allowance need be made in adjusting the tappet clearance for a hot and a cold engine as is required with long valve-stems and push-rods. The entire head can be removed within 15 min., and the entire valve mechanism can be adjusted on the bench if desired. For a test, I have removed the camshaft from the engine in 4 1/2 min., purposely disarranging the adjustment of the valves while doing so. The reassembling of the camshaft and the adjustment of the valves was accomplished within 6 min. This reassembling time cannot be approached with any other type of engine. The timing of the camshaft and of the distributor is done after the

engine is assembled and entirely by gears in the head. A vernier adjustment permits a setting within 2 deg.

Cost

Contrary to the popular idea, a well designed overhead-camshaft engine is no more expensive to build than other types. Owing to the comparative simplicity and compactness of the crankcase and the cylinder block, a considerable saving is effected in the cost of these parts and in the weight of the engine. This 3¼ x 5-in. six-cylinder engine without its accessories weighed only 360 lb.; the small weight is accounted for partly by the fact that the greatest width of the cylinder block or head is 5 1/2 in. Also, the machining operations cost less because the design of the mechanism is simpler than is usual. The head for an overhead-camshaft engine is more expensive to build than that for other types but, as the mechanism is more compact, the cost of the parts is less and the total saving in weight for the complete engine is about 20 per cent. Both material and labor costs are less than for an L-head engine of an equal bore and stroke.

THE DISCUSSION

V. A. Nielson:—How is the distributor lubricated?

R. Abell:—The engine that was built in Detroit had no means provided for lubricating the distributor other than such oil as it got from the engine cylinder. When the engine was put on the dynamometer for test, I put the distributor into its bearings when it was bone-dry; an oil-film was established automatically as soon as the engine started.

The Trego engine was built with a distributor 30 in. long, in one piece, and no trouble due to distributor warpage occurred. A means of lubricating the distributor was provided by drilling small holes from the chamber containing the camshaft in between the ports, so that the oil which always is present in the head would trickle down through these holes and provide sufficient lubrication; but, within about 30 min., we plugged these holes shut because they provided oil enough to make the engine smoke. The distributor never required any additional lubrication. Some oil is always going out with the exhaust gas, sufficient in amount for this purpose.

Question:—How much clearance is allowed between the distributor and its bearing?

Mr. Abell:—The distributor clearance is about the same as is allowed for the piston. It appears not to make much difference whether the clearance is 0.003 or 0.006 in. I have run a distributor that had a clearance of 0.012 in. and it did not show 1 lb. of difference on the dynamometer. When the engine is idling at low speed the amount of clearance makes a slight difference. This results in a greater amount of dilution; that is, the vacuum in the intake draws over more exhaust-gas and dilution occurs to such a degree as may cause a cylinder to miss and thus develop irregular running; but the engine will not stop. With a large distributor clearance, the engine will run at less than 180 r.p.m.

Question:—Why does not the cooling water heat-up under the conditions you have specified?

Mr. Abell:—The explanation is complicated; the four contributing factors are

(1) The valve does not reach half the present maximum temperature of the ordinary valve, and no hot-spots are present to boil the water

(2) The hemispherical combustion-chamber presents a minimum of heat-absorbing surface to the hot gases and has a maximum of cooling surface in contact with the water; in addition, it permits more complete combustion

(3) The higher compression-pressure permitted also improves the combustion so that there is a lower average temperature of the exhaust gas

(4) The additional exhaust-gas taken back with the new charge reduces the maximum flame-temperature by several hundred degrees fahrenheit.

All of the four factors enumerated, considered together, reduce the temperature of the cooling water as compared with that of ordinary types of engine having separate valves.

Ricardo states that, when changing compression on his test engine, the exhaust-pipe will become red-hot for a certain distance under the lower compression-pressure. He says that when he increases the compression-pressure, the red-hot section is shortened in proportion to the amount of the increase in the compression-pressure. He says also that each 1 per cent of exhaust gas added to the fuel charge reduces the flame-temperature 45 deg. fahr. This reduction in the flame-temperature was what I sought to accomplish.

Question:—Have you made any test in which you used only one spark-plug?

Mr. Abell:—All tests were made when using single ignition.

Question:—What is the amount of pressure of the valve against its seat?

Mr. Abell:—The only pressure against the valve-seat is that produced by inertia and by gas pressure. The valve is not pulled against its seat mechanically. When the engine is not running, the valve is not resting against its seat; by taking hold of the valve-stem, the valve can be spun around. The adjustment is to draw the valve against its seat, so that it can be felt to touch its seat, and then to back it off for 1 or 2 points of the castellated nut and insert the cotter-pin.

Question:—Have you ever operated the engine with a combustion-chamber that was not machined?

Mr. Abell:—Yes. On the Chevrolet engine used, the combustion-chamber was not a true hemisphere and it was not machined. Running under 115-lb. per sq. in. gage pressure and after a two-week run, slight signs of "pinking" were noticed. We found some traces of carbon deposit in the corners of the combustion-chamber, but this would not have occurred if the combustion-chamber had been a true hemisphere in form.

Engineers and Production Managers

By [illegible]

Cleveland Section Paper

After [illegible] the benefits conferred on [illegible] and thus transferred to mankind by the [illegible] the author points the duties of the engineer and of the production manager and describes the attitude of mind that each usually has toward the other, an attitude that is too often unfavorable.

Asking whether this is due simply to a lack of cooperation, to the differences in their training and education or to the differences in the requirements of the two positions, the author analyzes these requirements in some detail and concludes that the engineer, as the creator, should have the confidence and the enthusiasm of an organization, supply all of the departments with the energizing power and be the dynamo; and that the production manager, as the producer, should embody the conservation of an organization, be the motor and not the dynamo. The two positions should constitute a close working harmonious unit.

THROUGHOUT the last century, the engineer has given marvelous evidence of a continuous growth. His development of towns, cities and countries exemplify this; as do also his development of industry, his employment of labor and the improvement of labor conditions, the phenomenal advance in numbers of products, his development of the modern home and his service to the entire world of intellectual people and barbarians as well. Examples of some of the late proofs of his service are the automobile, the airplane, wireless communication and electrified railways. Thousands of other improvements are products of the brain of the engineer; he is the creator and is recognized as such by the populace. The names of Edison, Steinmetz, Marconi, Haynes, Ford and many others are all household words. They are engineers in the progress of science, of invention and of service to humanity; they have given proof of the growth of engineering service. The engineer stands preeminent in the shouldering of responsibility and in the safeguarding of human life. The safety of a bridge, of a building, of riding in an automobile, a train or any passenger conveyance is due to the training, perseverance and knowledge of the engineer. His work is not alone the subject of inventive planning and building; he must always have in mind that a deep and far-reaching responsibility is his [illegible] humanity suffers for any false move or wrong calculation. In no other profession are as exacting demands made.

When we stop to consider the possible consequences of the mistaken judgment of an engineer, we can realize his responsibilities. We, as engineers, invent, plan and build, having before us at all times safety, service and satisfaction. We must build well, serve well and please the critical mind of a judging public. That the engineer has accomplished these results is fully demonstrated in our everyday lives as we come into contact with the products of his endeavors. But he is not infallible, nor is he free from the criticism to which all men of initiative are subjected. He is an essential in the scheme of life, but only in connection with his fellows. Probably the nearest co-operator with whom he comes into contact is the production manager or the brain that makes the engineer's ideas a reality.

[illegible] Engineering Extension Co., Cleveland.

Engineering and Production

Leaving out of consideration the subjects of finance, equipment and organization, although they are essential in the progress of engineering, the object of this paper is to point out the cooperative spirit that is so necessary between engineers and the men responsible for production.

When we pause to consider the position of the production manager, we must realize that his pathway is not one on which he goes Rolls-Roycing over boulevards. He has his sharp turns to make and his rough roads to cover; the semaphore is probably thrown to "stop" for him as often as it is for the engineer. However, the rough roads, sharp turns and stop signs do not bother a production man; he has the reputation of being a good driver. "Ask the men he has driven."

Many compliments have been paid the engineer by engineers, but let us put the engineer into the heart and the mind of the production manager and see ourselves as he sees us. Then our beautiful pedestal has crumbled away and, somehow, we have tumbled into the big mass of humans.

I have asked the production manager his definite opinion of an engineer. He thinks an engineer is a "nut" who sits in an office that has its walls plastered with diplomas, degrees and dust; who wears a woe-begone expression on his face, feeds on the end of a pencil and carries his brains on a slide rule; whose talk is confined to stresses, bending moments, section moduli, theorems and isms; who can tell you more about the thing you know nothing about and do not want to know and less about the thing he knows and thinks you should know, than any other being on earth.

But the production or the factory manager does not have a monopoly on thought. The engineer defines the production manager as a well-fed, ruddy-faced individual who sits in an office far removed from the engineering office and who thinks only in terms of jigs, tools, fixtures, machinery, cores and patterns and production figures. The walls of his office are usually a maze of charts, blackboards and "the schedule"; his favorite opening speech to those who enter is "Well," and his password to those who leave is: "Sure, we can make anything, but remember that this plant is not run as a charitable institution."

What is the reason for these two so opposite definitions? Is it due to a lack of cooperation on the part of engineers and production managers, to the differences in their training and education or to the differences in the requirements of the two positions in an organization? It may be due to a feeling on the part of both that they have not taken full advantage of their opportunities. The engineer may feel that he has not labored in the shops and familiarized himself with the problems of production. The production manager may realize that he has not fortified himself with a knowledge of engineering. Thus both men would be in a position of being always on their guard.

It is a perfectly natural desire on the part of each one of us to wish to be intelligent and to hold our own in discussion incident to our special business. As a rule, the production manager is a man who has worked his way

up step by step through the ranks at the factory; he has lived with the purr of the wheels in his ears and has rubbed shoulders with his fellow men from the sweeper to the superintendent; blueprints have been his Bible. He has learned that press fits are possible only in certain limit dimensions, that a straight line is the shortest distance between two points and that simplicity, accessibility and machinability spell speed, reduced costs and profits. His mind is trained to read a blueprint, not as a work of art, but as a dollars-and-cents proposition. His viewpoint of a blueprint is not as a finished product, but as a series of operations to be performed by machinery for which his factory is or is not fitted. He sees the doughnut from the mixing of the dough through its various stages to the final fried cake and its final conversion into "dough"; but the engineer sees a hole surrounded by a ring of browned, crispy, delicious cake that pleases the eye and appeases the appetite. Both men are optimists, but one views the doughnut as a commercialist and the other as an appeal.

However, it should be borne in mind that the appeal must always be made just before the instinct of commercialism has its opportunity and, in making his appeal, the engineer of today will discover that success requires of him a more complex knowledge of business essentials than was required of his brother of yesterday. That he confines himself to the problems of design and to engineering alone is not sufficient; he should fortify himself with a knowledge of production, the methods of machining, the costs of manufacturing and the possible commercial limits of machine operations. He should take a course of training in the factory or, through a close cooperation with the production manager, gain step by step a general knowledge of production requirements and of the instincts of commercialism.

The production manager also can learn from the engineer facts that will make him a more valuable factor in his organization. We all have heard the remark made by the production department to the effect that, if the engineering department had used an ounce of horse sense and got down to brass tacks on such-and-such a design, profits would have been made instead of having a receiver at the helm. In all of this, there may be some justification. Many business failures have been defined by A. R. Erskine, president of the Studebaker Corporation of America, as follows: "First, the lack of simplicity and directness in methods; second, to rely too much on theory and guesswork and too little on facts."

"Cooperation" an Essential Slogan

Business policies or decisions based on pure opinions lead to definite trouble that a direct diagnosis and cooperation on the part of departmental heads would avoid. No business can be run unless all departments have the essential facts in hand. To conceive, to design and to invent are simple enough for those who are technically trained but, if we are not in accord with the fundamentals of production, simple and direct in our administrating and manufacturing, we have failed as progressive engineers of the times. We should exercise caution and cooperation before taking action on engineering designs, and our nearest co-partner should be the production manager.

The time to gain his confidence and to benefit by the cooperation and ability of the production manager is not after a design has been completed and put into production but at the time of its inception. Let him criticize, tear apart and make suggestions. With the proper spirit of cooperation that is essential in any well-regulated organization, we will be surprised to find that brains are brains whether in the head of an engineer or that of a production manager. The combination of these brains, working in close cooperation in an organization, will result in the saving of millions of dollars to industry that are now wasted. Every design, every detail and every drawing that is not the subject of study and discussion with the production manager adds its small or large quota to the already large waste of materials, effort and money.

When we stop to consider what the saving of a pound of material on a volume-production basis means, we can grasp the necessity for this close cooperation between production and engineering. The slight changing of a pattern, the adding of a boss, the changed location of a drilled hole, all simple operations and appearing to be of little consequence, may constitute the difference between a profit or a loss on a product. The expense of tooling, of manufacturing and of assembling are determined by the design. Therefore it is to the advantage of a manufacturer to study carefully his engineering and production departments and see that they live in the same house. The engineer, as the creator, should have the confidence and the enthusiasm of the organization. He should supply all departments with energizing power; he should be the dynamo. The production manager, as the producer, should be the brakes and the conservatism of an organization. He should be the motor and not the dynamo.

Last fall the Society held a Production Meeting at Detroit, the first of its kind held by the Society and probably the best attended professional meeting of the Society. The second Production Meeting will be held at Cleveland this month, and this meeting is drawn to your attention to show that the question of production on a quality basis is having the attention of engineers. Efforts are being made to draw the production and the engineering departments into the close harmony and cooperation that is desirable if we are to serve the public honestly and to the best of our ability.

Future Demands

I have endeavored to point out briefly the responsibilities of the engineer and of the production manager and to show that the two positions should constitute a close working, harmonious unit. That this condition does not exist, in many cases, is demonstrated by the changing requirements of the engineer. He is being urged to take up the problems of manufacturing and production.

In many manufacturing organizations the production engineer is becoming a reality. He is the technically trained man who steps into manufacturing with a double-barreled knowledge at his command, that of engineering and manufacturing. In some cases the production engineer is an intermediate between the manufacturing and the engineering departments, the man within the organization who makes final decisions on engineering, manufacturing and quality. Where we find the production engineer in this position, we will find an organization slightly out of tune. Cooperation probably exists, but the question of the volume of production is uppermost and probably is demanded of the production manager; this results in a lowering in the quality of the product in the anxiety to meet the production schedules. The production engineer in this organization fulfills a most valuable service. He is familiar with the engineering requirements of the product; he sits in judgment on the quality of workmanship and manufacturing that is to be acceptable as the finished product; he is engineer, in-

The engineer, the production manager and the production [illegible] are essential to industry. They are dependent upon each other to a greater extent than are the heads of other departments. Therefore it is the duty of each of these other heads of industrial departments, oftentimes, to smother his pride, to give and take, to work hand in hand and to cooperate so that industry can progress in economy, quality and service to all the peoples of the earth.

TESTING OF MATERIALS AND ITS EFFECT ON ENGINEERING

(Concluded from p. 300)

WHITNEY SLAGHT:—Would it be possible to use the same methods for testing aluminum alloys as for alloys of steel?

PROFESSOR UPTON:—So far as fatigue testing is concerned, we expect to work them in the same way.

MR. SLAGHT:—Then the properties of aluminum alloys do not require a different method of testing than those of steel?

PROFESSOR UPTON:—If they are intended to withstand the same stresses as steel, they should be tested in the same way.

W. R. GORDON:—What does Professor Upton consider the proper uses of aluminum bronze? What are its possibilities as a bearing-metal?

PROFESSOR UPTON:—Do you mean a 10-per cent aluminum bronze? This will have a tensile-strength of about 100,000 lb. per sq. in.

MR. GORDON:—Yes. Would you consider it a proper metal for worm-gears?

PROFESSOR UPTON:—I would not like to say. I know that it is being tried out. The only sure way of finding out is by testing. No abrasion machine produces results that we do not question; so, the only way is to test the material in service.

MR. MILLER:—Do you prefer the Rockwell to the Brinell test for hardness?

PROFESSOR UPTON:—The Rockwell test is the same in scheme as the Brinell, and differs only in details that rather favor the Rockwell. The Rockwell has a diamond point instead of a steel ball and makes a small impression of about the same size as does the scleroscope hammer. Sometimes the Brinell ball deforms before the material that is being tested does. The Brinell principle is correct and has been worked out with a diamond ball. We cannot afford diamond balls, but we can afford small diamond points. The Rockwell machine does a thing that the Brinell does not do. It puts on a load of 10 lb., then a 100-lb. load, and then goes back to the initial 10-lb. load. The gage is read with the initial load and is checked when it comes back the second time. You get definite contact with a piece. The shape of the conical impression is always the same, regardless of its size. You do not get this with the Brinell machine.

MR. MILLER:—We find the Brinell test very satisfactory for steels of moderate hardness, but it is not so good for very hard steels.

PROFESSOR UPTON:—With the Rockwell instrument, you can go up through all the harder steels. This is partly due to the shape of the diamond, which is conical; whereas, in the Brinell test, a steel ball is used. It is also partly due to the initial load of 10 lb.

Hydraulic Four-Wheel Brakes for Automotive Vehicles

By Malcolm Loughead[1]

Detroit Section Paper *Illustrated with* Drawings

FOUR-WHEEL brakes actuated by hydraulic pressure were described and discussed in a paper presented by Mr. Loughead before the Detroit Section in May, 1923, and the paper, with additions, was to have been presented at the Semi-Annual Meeting at Spring Lake, N. J., in June, 1923. Since Mr. Loughead was unable to attend the latter meeting and present his revised paper, the only discussion by members was that offered at Detroit, and it follows the revised paper printed herewith.

ABSTRACT

FOLLOWING a discussion of the braking ability of rear-wheel brakes only, front-wheel brakes only and brakes on all four wheels, the author answers citations in disfavor of four-wheel brakes and compares external with internal brakes in favor of the external type.

The hydraulic four-wheel brake system is illustrated and described in detail, and a statement is made of four-wheel-brake design requirements. These are: Reliability, equalization, stopping ability, control, simple adjustments, minimized service requirements and provision against wear. Each requirement is then sub-divided and given separate consideration, claims being made in regard to how well the hydraulic system meets each requirement, with reasons therefor. A summary of the main advantages of the hydraulic compared with the mechanical type of four-wheel brake is made in conclusion.

Whether automotive vehicles should or should not be equipped with brakes on the front as well as on the rear wheels is a subject of vital importance to the entire industry. The number of deaths caused by automotive vehicles in the United States alone is appalling, especially when we acknowledge that a very high percentage of these accidents could be eliminated if all automotive vehicles were provided with adequate and properly designed braking facilities. Most of our tests of four-wheel brakes have been made at a car speed of 30 m.p.h. but, at this speed, only a small percentage of present-day automobiles equipped with conventional two-wheel brakes can be stopped within a distance of 130 ft., even when these brakes are adjusted and lubricated properly.

Disadvantageous Features

Two points commonly cited against the usage of four-wheel brakes are the possibilities of locking the front wheels and of rear-end collisions caused by a too sudden stoppage of the car, with the failure of the car behind to stop likewise. If front-wheel brakes are not designed properly, they may lock the front wheels and cause a serious accident due, among other possibilities, to radical interference with the steering ability. My experience is that it is advisable to make the front and the rear brakes of the same design and size; otherwise, if the rear brakes are larger than those in front, there will be a sacrifice of stopping ability under dry-pavement conditions. If the front brakes are larger or more efficient than those at the rear, they will lock the front wheels, especially when the coefficient of friction of the pavement is low. No accidents due to the locking of front wheels of cars equipped with our four-wheel brakes have been reported.

Danger from rear-end collisions lies more in theory than in actuality. They have occurred in a few instances, but the resultant damage has been slight. Damage to lamps and radiators is more expensive than that done to rear tires and fenders, but the car that follows another usually runs 15 to 30 ft. behind and has that much additional space within which to stop.

External versus Internal Brakes

With regard to the expansion of brake-drums on account of heat generated by friction, the external has a decided advantage over the internal type of brake. When the internal type is used on a long grade, when several successive and severe applications of it are made and especially when the foot-pedal adjustment is very close to the toe-board, the expansion due to heat may reach an amount such that the car is virtually without brakes although, with the same adjustment, the brakes may function perfectly when cold. The opposite condition obtains with the external type; the hotter the brake-drums become, the greater the available pedal-travel will be, a point often overlooked in emergency-brake design and one that can cause a serious accident if a car having hot brake-drums is left standing on a hill.

Oil leakage from the rear axle and over-greasing of front wheels commonly cause internal brake-shoes or bands to become saturated with oil and grease so that the car is practically without brakes, but this is much less likely to occur with the external type of brake. Distortion as well as expansion must be provided against for brakes of the internal-shoe type, and it is very difficult to attain as high a ratio of pedal movement to brake-shoe movement for a given pedal pressure as can be realized with the external type.

To design a brake-drum that will not distort is largely a matter of weight and cost. My experience is that the cost of a drum built rigidly enough to withstand the pressure of internal shoes without becoming distorted will be triple the cost of a pressed drum suitable for external brakes.

The Hydraulic System

Pressure in the hydraulic four-wheel-brake system is built-up in a cylinder mounted on the transmission case near the fulcrum of the brake-pedal. Fig. 1 shows the layout, including the master cylinder, the piping and the reservoir tank. A piston in this cylinder is connected directly to the lower end of the brake-pedal forging, as shown in Fig. 2, and is forced into the cylinder

[1] Chief Engineer, Hydraulic Brake Co., Detroit.

the depression of the brake-pedal itself. The ratio of the movement of the pedal to that of the piston is about 4 to 1. Four copper pressure lines or tubes lead from the master cylinder to points on the chassis frame adjacent to each of the four wheels, as indicated in Fig. 1.

Mounted rigidly on the dust shield or anchor bracket at each one of the four wheels is a brake-band-actuating cylinder that is connected to the pressure line on the chassis frame by a suitable length of seven-ply rubber hose capable of resisting a pressure of 2000 to 2500 lb. per sq. in. before bursting. A section of the hose assembly is shown in the lower portion of Fig. 3. The hose has a close-wound coil-spring inserted while the hose is under a pressure of 1200 to 1400 lb. per sq. in. There is practically no expansion loss up to a pressure of 1000 lb. per sq. in., this being a very important factor with hydraulic brakes because two movements, those of steering and of spring action, must be provided for by using flexible connections. An expansion loss in the hydraulic system causes a lessening of the amount of pedal travel; to compensate for this loss it is necessary to reduce the amount of pedal leverage and this would require a greater pedal pressure.

The copper tubing used for the pressure line on the chassis is supported by clips inside the channel-iron of the frame and terminates opposite each wheel in a standard union nut or coupling. We have never had a failure of brake action due to copper tubing when it was used as a non-flexible member. In some of our first installations we used a coil of copper tubing at each of the brake-bands to take-up the movement, but leaks developed due to the flaring of the tube. The present tubing is not allowed to flex, and I attribute the absence of tubing trouble also to the support of the tubing by the union nut instead of by the flared end of the tube. I have had three failures of the gasoline pipe-line, and each showed a radial crack at the base of the flare of the copper tubing.

Brake-Actuating Cylinders

Each of the individual brake-actuating cylinders on the front brake-supports contains a pair of opposed pistons, one at either end of the cylinder. The brake-actuating-cylinder assembly is shown in Fig. 3 also. These pistons act against two levers that are, in turn, connected to the brake-band ends, the brake-bands being of the external contracting type. Liquid is admitted to these brake-actuating cylinders between their opposed pistons through an opening at the cylinder centers. When the brake pedal is depressed, the opposed pistons in each cylinder are forced apart by the hydraulic pressure set-up in the system by the master cylinder; one end of each of the levers in each brake-actuating cylinder bears on the head of one of its opposed pistons and the other end exerts a pull on the brake-band end, drawing it tangent to the drum. Smooth brake action is assured by drawing the brake-band ends in a line tangent to the brake-drum and not allowing the ends to "snub." Since the opposed pistons are forced apart by hydraulic pressure, it follows that the pressure on both pistons in all four brake-actuating cylinders must be equal. The brake-actuating-cylinder group-assembly is shown in detail in Fig. 3.

Liquid Composition

A mixture of alcohol and glycerine, 40 per cent alcohol and 60 per cent glycerine, constitutes the liquid used in the hydraulic braking system. Any leakage of liquid from the system is compensated for from a small reservoir mounted on the dash that replenishes the master cylinder automatically. When the master-cylinder piston is in the "off" position, it uncovers several small port-holes, each about 0.02 in. in diameter, that communicate directly with the reservoir. This allows a free flow of liquid from the tank to the master cylinder and replenishes any loss of liquid that may occur during the application of the brakes. If there is any loss of liquid, it is very slight; in fact, we have run cars for several months with a closed line and have lost practically none of the fluid. Rawhide is used to pack the pistons and prevent any leakage of the fluid from the hydraulic cylinders.

Four-Wheel-Brake Design

In the design of a thoroughly satisfactory four-wheel braking-system, the following six factors are of prime importance:

(1) Reliability
(2) Equalization
(3) Stopping ability
(4) Control
(5) Simple adjustments and minimized service requirements
(6) Wear and replacement of parts

For reliability, three conditions are essential; (*a*) a high factor of safety throughout the system, (*b*) that all movable parts function as designed and that the least

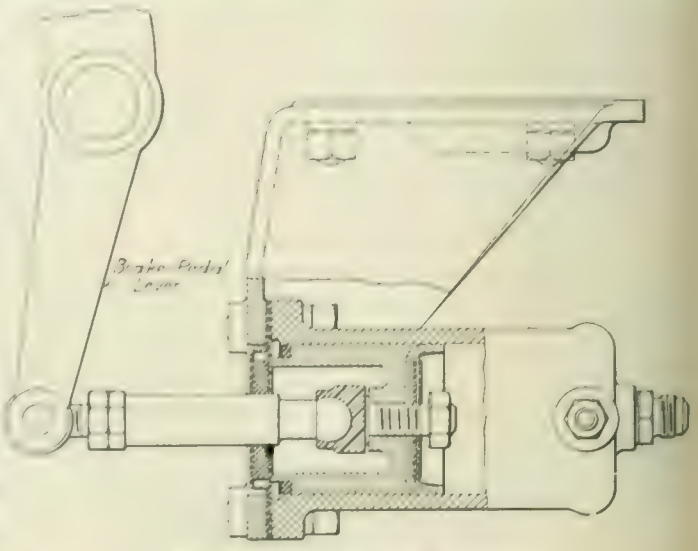


Fig. 2—Master Cylinder Assembly

possible number of orifices for their lubrication be included and (*c*) that satisfactory performance be attained during all kinds of weather conditions.

A high factor of safety is provided in the flexible hose, the weakest part of the system. Its bursting pressure is 2000 to 2500 lb. per sq. in. and the maximum pressure to which it is subjected in an emergency stop is 300 lb. per sq. in. The pedal clevis-pin is the only movable part that requires lubrication; it is well protected under the floorboards and is accessible. The alcohol content of the alcohol-glycerine fluid can be increased for low-temperature conditions; hence, the system is independent of severe low temperatures.

Equalization

Proper equalization of four-wheel brakes demands (*a*) that the application of the brakes should have no effect on steering ability; (*b*) that it should prevent skidding; (*c*) that it should prevent locking of the wheels, especially the front wheels, and (*d*) that it should not reduce the braking effectiveness under varying road conditions.

Steering ability is not affected in the hydraulic system because the pressure of the liquid is the same in all parts of the system and perfect equalization obtains up to the brake-band ends. Variations in the coefficient of friction of the brake-linings, such as may occur when one front brake becomes wet, tend to make that brake more effective than another. By locating the center-line of the knuckle-pin so that its projection is ½ in., or less, from the center-line of the tire on the ground, the rise in the coefficient of friction of the saturated brake is not noticeable and no effect is transmitted to the steering-wheel even at high car speeds.

As a means of preventing skidding, the four-wheel brake is efficient only to the degree of equalization attained. Positive equalization is secured up to the brake-band ends in the hydraulic system. This claim of positive equalization has been questioned by engineers who say that any great variation in the coefficient of friction of the brake-lining would offset the admitted equalization up to the brake-band ends. For the most part, such variations in the coefficient of friction result from heat generated during a long-continued brake-application and would affect each brake proportionately. Therefore, the change in the coefficient of friction cannot be said to affect equalization at each of the wheels but, rather, would result in requiring a greater pedal effort to accomplish a given result. Assuming that a change in the coefficient of friction is not distributed equally to the four wheels, it is none the less desirable and necessary to maintain equalization in the operating mechanism, unless one argues that two wrongs make a right.

Some means to release the brakes somewhat, at the time the wheels stop rotating, is necessary to prevent locking of the front wheels without reducing braking effectiveness under varying road conditions. Some experiments have been made by others, and we have followed European attempts to accomplish this release of the brakes, one being to have each wheel equipped with one or more weights, the centrifugal force of which tends to release the brakes as the car speed decreases. But this is not commercially practicable and we have found no other way of incorporating the principle with a successful brake.

Stopping Ability

Some engineers have advocated a longer rather than the quickest possible stop and have contended that abrupt stops will result in frequent rear-end collisions and much property damage, but a questionnaire answered by 1000 users of the hydraulic four-wheel brake reports very little damage of this character and proves it to be a matter of education. A car driver appreciates the security afforded by this type of brake but will not subject himself and his passengers unnecessarily to the inconvenience resulting from a very sudden stop.

TABLE 1—TESTS OF STOPPING ABILITY OF HYDRAULIC FOUR-WHEEL BRAKES

Model 57, Cadillac Phaeton Car—Speed, 30 m.p.h.		
Total Weight, with Driver, lb.		4,400
Weight on Front Wheels, lb.		2,000
Weight on Rear Wheels, lb.		2,400
Tires	Make	Mason Cord
	Size, in.	35 x 5
	Pressure, lb. per sq. in.	65
Road Surface		Dry Concrete
Stopping Distances; Average of Five Stops.		Ft.
Brakes Applied on	Rear Wheels Only	89.2
	Front Wheels Only	67.6
	Front and Rear Wheels	36.8

Tests of the stopping ability of the hydraulic four-wheel braking-system were made recently, the results being stated in Table 1. A pistol was mounted rigidly on the chassis of the car; its trigger was connected to the brake pedal and set to fire a bullet into the road surface when the pedal had moved 1 in. After the car had been brought to a stop, the distance from the muzzle of the pistol on the car to the imprint of the bullet in the road surface was measured with a steel tape. The stopping distances stated in Table 1 are an average of five stops in each case, and all stops were made from a car speed of 30 m.p.h.

With a car fully loaded, our tests show that it is necessary to provide 1 sq. in. of brake lining for each 12.5 lb. of car weight. If the ratio of the car weight to the area of the brake-lining is increased to more than 16 lb., the surface of the lining may burn and cause a decrease in the coefficient of friction.

The ratio of 12.5 lb. of car weight to 1 sq. in. of brake-lining conforms fairly well with standard practice. Considering a car that carries seven passengers, weighs 5360 lb. and has 3200 lb. of this weight on its rear wheels, we find the average area of the brake-lining to be 225 sq. in., approximately; this gives 14.5 lb. of car weight

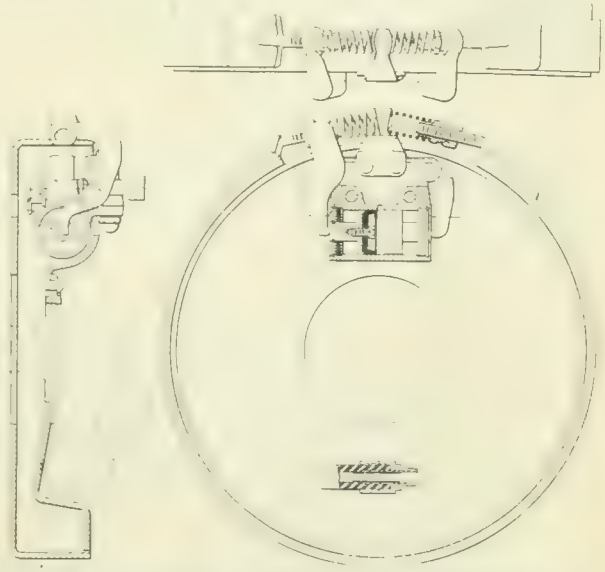


FIG. 3—WHEEL CYLINDER GROUP ASSEMBLY WITH A SECTION OF THE HOSE END SHOWN IN THE LOWER PORTION

[illegible] light pedal-pressure, [illegible] a maximum length of pedal stroke and [illegible] a constant pedal-pressure for any given stop.

[illegible] of the low friction loss in the hydraulic means of brake application, the high friction loss of the mechanical [illegible] is avoided and it is therefore possible to use only a moderate pedal-pressure without employing [illegible] servo-mechanism. A positive brake release is accomplished because there are no mechanical joints or bearings to freeze or seize. The brake members are returned positively to their normal position after the release of pressure by an adequate return spring. A minimum length of pedal stroke is permitted because there are no built-up losses of motion due to a multiplicity of mechanical joints. Each inch of pedal stroke is productive of work at the brake-band ends. The pedal pressure remains constant for any given stop, except as it may be affected by variations in the uniformity of the brake-lining and this, in our experience, is not a large factor, because of the effectiveness of the hydraulic actuating means.

Simplicity of Adjustment

Desirable adjustment features that minimize service requirements are (*a*) simplicity, (*b*) infrequency and (*c*) accessibility.

No adjustment for brake equalization is required by the hydraulic system; the inherent equalization in the actuating means is complete throughout so long as the friction members are functioning. Adjustments for wear will be infrequent if a liberal area of brake-lining is provided by the design, say 1 sq. in. of lining for each 12.5 lb. of car weight. Cars equipped with hydraulic brakes have been driven 8000 miles without adjustment.

Regardless of the simplicity of adjustment that is provided, many users will neglect adjustments unless they are made accessible, and adjustments should be of a character that do not require skilled service. The average owner-driver should be able to make them quickly and with certainty, and he can do this for hydraulic brakes.

Wear and Replacement

Other desirable factors of satisfactory brake performance are (*a*) an infrequent replacement of the brake-lining and the consequent removal of the vehicle from service and (*b*) that wear in the actuating mechanism be reduced to a minimum.

We have records of many cars in service that have hydraulic four-wheel brakes and have run from 25,000 to 35,000 miles without requiring a relining of their brakes. The wear in the hydraulic system can be said to be negligible and the mechanism should outlive the car. It is obvious that removing all necessity for sliding the rear wheels to make an emergency stop, which is accomplished by the use of four-wheel brakes, will result in saving the rear-wheel tires from wear.

Advantages of the Hydraulic System

Inherent equalization is secured in the hydraulic system of brakes. Exactly the same pressure is applied to each of the four brake-bands by utilizing a column of liquid under pressure against pistons acting in cylinders adjacent to the brake-band ends, and equalization is thus maintained regardless of brake-band adjustment.

Since there are fewer mechanical joints, the friction is lowered considerably. This advantage becomes pronounced after several months of service when, due to a lack of proper lubrication, brakes of the mechanical type show wear in some joints and seizing or binding in others.

The flexible connection between the brakes and the chassis prevents trouble due to the improperly related movement of a mechanical brake-linkage.

Brake adjustment is not affected by a change of loading in the car. The movement of the car body in relation to the axles when traveling over rough roads does not react against the brake pedal. This reaction does exist in some forms of mechanical brake and is particularly noticeable when coasting down a rough grade because the brakes then have a tendency to lock and release alternately, due to the movement of the car springs. The operation of the hydraulic system is very smooth on the roughest of roads.

Pedal-pressure requirements are moderate in the hydraulic system and, with a pedal stroke of 5 to 6 in. and a moderate pressure, the necessity of utilizing any servo-mechanism is eliminated by taking advantage of the low friction loss, absence of lost motion and external-band brakes anchored to give approximately 200 deg. of brake-lining in contact with the brake-drum on the wrapping end and in the forward direction of rotation.

THE DISCUSSION

QUESTION:—What liquid is used?

ANSWER:—We use an alcohol-glycerine solution, approximately 60 per cent glycerine and 40 per cent alcohol.

QUESTION:—How does the cost of hydraulic brakes compare with that of mechanical four-wheel brakes?

ANSWER:—That depends somewhat on the design of the mechanical brakes. To date we have seen no mechanical brakes that are equal in cost to hydraulic. We can build the toggle-joint system as used on some foreign cars for a little less.

QUESTION:—What about the design of front axles to which four-wheel brakes are applied, as regards the effect on the steering?

ANSWER:—Placing the intersecting lines of the knuckle ½ in. or less from the center-line of the tire does not affect the steering much. We have a car that is running now in which the line is ⅜ in. from the center of the tire; the car when traveling at a speed of from 65 to 100 m.p.h. could be stopped with one wheel completely shut off, practically without moving the steering-wheel.

QUESTION:—In case the operating fluid congeals or freezes in cold weather, what means of operating are provided?

ANSWER:—In extremely cold weather we run the alcohol content up the same as we should with radiators.

QUESTION:—When city ordinances require two sets of brakes, are independent mechanical means of operation provided?

ANSWER:—In that case we recommend an emergency brake, if for no other reason than locking the car when it is standing.

QUESTION:—Is there no emergency brake otherwise?

ANSWER:—None, except either the drive-shaft brake or the internal brake used in conjunction with the four outside brakes, which are operated by the hydraulic system.

QUESTION:—Are the rear brakes designed to take effect slightly ahead of the front brakes, on account of the greater weight at the rear end of the car?

ANSWER:—No; because even though there is more weight on the rear axle, in the ratio of 60 to 40 per cent, as, of course, we all know is the case, in stopping with four-wheel brakes the shifting of the center of gravity of the car makes the braking of the front wheels more effective than that of the rear wheels.

As an illustration of the shifting of the center of gravity, braking the front wheels of a car traveling at 30 m.p.h. will stop the car in 67 ft. while braking the rear wheels will stop it in 89 ft., which means a decided shifting of the weight; the rear wheels tend to slide before the front wheels even though more weight is at the rear.

QUESTION:—What would happen if a connection or a pipe should leak or break?

ANSWER:—The same thing that would happen if the threaded end of a brake-rod should break, a contingency that is not uncommon. Our system of piping has shown no breakage, and I should say that the percentage of failures would be no higher than that of the threaded ends of brake-rods. You would have to use a brake in either case, whether mechanical or hydraulic.

QUESTION:—Would there be an indicator on the reservoir to indicate that a leak had occurred in the system?

ANSWER:—No; if there were a leak in the system sufficient to cause a failure, the pedal would not remain in position but would drop to the floor-board when it was applied.

QUESTION:—Are the torsional strains on the axles greater or less when 32 x 7-in. tires are replaced by 35 x 5-in. tires?

ANSWER:—The coefficient of friction is the same whether it be distributed over 10 or over 2 sq. in.

QUESTION:—What effect has front-wheel camber on front-wheel brakes?

ANSWER:—It is taken into account only in designing to make the intersecting line of the knuckle-pin come within ½ in. of the center of the tire.

QUESTION:—Can you give the weight that was added to the Cadillac front axle in the test referred to?

ANSWER:—The axle itself was designed to take the torque load as well as the bending load of the weight of the car. The axle is 12 oz. lighter than the former Cadillac axle; I have no exact figures as to the weight of the drums and the rest of the mechanism. The drums weigh approximately 20 lb. each; the bands and the rest of the mechanism would weigh possibly 15 lb.; between 70 and 100 lb. on a car of that weight.

QUESTION:—Do you find that front axles at present are ample in most cars to withstand the torque of front-axle braking?

ANSWER:—No; they have not a sufficiently high factor of safety. We recommend a better torque-section from the spring pad to the outer wheel or the knuckle.

QUESTION:—Can an internal brake be designed to wrap internally?

ANSWER:—Yes; but not with the same efficiency as an external band. We have shown on tests that when an external band is operated by a straight pull between the gap ends, that is, in a straight line, and an internal brake is used on the same drum and expanded in a straight line, the external brake develops 35 lb. and the internal brake 25 lb. In other words, the efficiency of the two is as 35 to 25.

W. C. KEYS:—Were the bands anchored at the middle in each case?

MALCOLM LOUGHEAD:—They were anchored 180 deg. from the center of the gap.

QUESTION:—How much stronger, approximately, in per cent must the front axle be with front-wheel brakes?

ANSWER:—To give a torsional section. The bending section, of course, is still there and is sufficiently strong.

QUESTION:—Would air in the system have any effect on the action of the brakes?

ANSWER:—It would mean a loss of pedal travel; if there were sufficient air the pedal would go clear to the floor-board without actuating the brakes, so that we take practically all the air out, that is, within a very small fraction of 1 per cent.

QUESTION:—What effect have very cold and very hot weather on operation?

ANSWER:—There is slightly sluggish action with the fluid that we use when the weather gets below zero. This can be counteracted by increasing the alcohol content, which will bring the action back to normal.

QUESTION:—Is tire mileage increased by using four-wheel brakes?

ANSWER:—Yes, considerably. There is practically no necessity for ever sliding the tires with four-wheel brakes; this happens many times a day with two-wheel brakes in traffic, without taking into consideration the conditions in mountainous districts.

QUESTION:—In the ratio you gave of 12½ lb. of car weight to 1 sq. in. of brake surface, is the brake surface the effective area or the total area of the brake-lining?

ANSWER:—The effective area; that is, the area after deducting approximately 4 in. of lining at the anchor-pin point on a 15-in. drum.

QUESTION:—What change, if any, is made in the front springs?

ANSWER:—None. We have never had a spring break. The spring makers have recommended that no change be made when four-wheel brakes are used. The front springs are as strong as the rear springs that take the torque loading in the Hotchkiss drive and the brake loading also.

QUESTION:—Are there two points of adjustment on each wheel?

ANSWER:—There are three on each wheel. One on each end of the band and one at the anchor-pin.

QUESTION:—What is the percentage of loss of liquid?

ANSWER:—That question is very hard to answer because the percentage varies considerably. We have never had a loss, have never had to refill the 2-pint tank in less than 6 months. The car I have mentioned, which has been running for over 20,000 miles, has shown no loss at all in a year's running.

QUESTION:—Is there churning of the oil? If so, what is the effect?

ANSWER:—There is some churning of the liquid, but it has no ill effect on the brakes.

QUESTION:—Is there oil leakage through the coiled wire tubing? If so, does this not rot the rubber casing and cause excessive loss of oil?

ANSWER:—The glycerine and alcohol has a preservative effect, if any, on the rubber.

QUESTION:—What is the minimum weight of car that can be economically equipped with four-wheel brakes? Would a Ford be a suitable car for four-wheel brakes?

ANSWER:—All cars, no matter what their weight may be, whether they are Fords or 6-ton trucks, can be stopped in the same distance; one can be stopped in as short a distance as the other, provided that the torque is sufficient to reach the point just before the wheels begin to slide. All cars should be equipped with four-

tare of less than 135 deg. fahr. Temperatures higher than this would injure the leather. In cold weather the ordinary leather cup gives good service, but in summer the heat forces the plugs of wax out of the leather, causing a gradual seepage at all times. We have absolutely no trouble when we use all rawhide packing.

We are making a search now and expect in a very short while to have a cup packing manufactured from fabric, rubber composition and the like, which would assure a uniform grade and a larger production than will any leather we might obtain. This packing has better possibilities from a production standpoint, though our present packing is giving us no trouble.

QUESTION:—What about the car behind that has rear-wheel brakes only?

ANSWER:—I think that is the business of the driver.

QUESTION:—Some builders of foreign cars are advocating that front-wheel brakes should be operated slightly in advance of rear-wheel brakes. What is the reason for that?

ANSWER:—Our reason for not doing it is that the shifting of the center of gravity always throws more weight on the front wheels, so that the rear wheels have a tendency to slide before the front ones, though the efficiency of the front wheels has not been increased. Many foreign cars with toggle operation of the shoe make this more necessary than does a balanced system of the hydraulic type.

QUESTION:—What minimum clearance do you allow between the lining and the drum?

ANSWER:—A minimum of 0.025 in. This will allow for expansion of the drum up to 650 deg. fahr.

QUESTION:—Does the brake-lining wear better with four-wheel brakes, or worse?

ANSWER:—Very much better. I might cite an instance of a Model-66 Pierce Arrow that weighs approximately 7000 lb. and carries 18 passengers, over the Ridge Road in California, which has a 7000-ft. rise. The rear brakes were relined after 48,000 miles, the front brakes after 32,000 miles of service. This shows the difference in efficiency between the front and the rear brakes on account of the shifting of the center of gravity.

QUESTION:—Is this particular hydraulic brake the type used by the Duesenberg car that won the Grand Prix?

ANSWER:—In principle, yes; but it is not the same in detail.

QUESTION:—What would the braking action be on the front wheels while turning a corner, as compared with straight running?

ANSWER:—If the brakes are properly equalized there will be no difference.

QUESTION:—How is the pressure of the brakes regulated to prevent sliding of the tires?

ANSWER:—That is another condition that varies so greatly with road conditions that it is almost impossible to put on a safety device that will keep the wheels from sliding. If a person puts too much pressure on the pedal it will cause the wheels to slide at times.

QUESTION:—Are the brake adjustments each independent?

ANSWER:—Yes, independent as regards taking up wear, but not as regards taking up equalization. They are inherently equalized at all times.

QUESTION:—How are the adjustments made?

ANSWER:—By two nuts, one on the head of each band extension, and by the conventional anchor-pin adjustment that is used on external brakes now.

QUESTION:—If the front wheels lock, do you not lose steering control?

ANSWER:—Absolutely. If a person puts his foot on the brake-pedal sufficiently hard to lock the wheels, he will lose steering control until he releases it enough to let the wheels revolve again. Cars that we have equipped have run an aggregate distance of 7,000,000 to 10,000,000 miles, with all kinds of average drivers, and have never had an accident on this account. There is only one thing to do, and that is to release the pedal slightly when you feel the wheels sliding.

QUESTION:—Does that mean that the ordinary driver must be specially coached in the use of four-wheel brakes?

ANSWER:—If he gets on a slippery pavement he must always be careful. He should work the brakes intermittently, as he would two-wheel brakes on ice. If he does not work the brake-pedal intermittently he will swerve round; we recommend that the pedal be applied in the same way with four-wheel brakes.

QUESTION:—The public would probably have to be re-educated in the use of four-wheel brakes?

ANSWER:—I should not think it would take much education; in the cars we have put out we have done no more than give warning of that condition and have never had trouble from that cause.

QUESTION:—Do you consider the use of chains on front wheels advisable?

ANSWER:—We have really forgotten what skid-chains are. We never use them any more. I have had one occasion in the last 7 years to use them and that was coming over the Tuscarora Mountains last winter on the ice. I have never used them on front wheels with four-wheel brakes. That includes two trips across the United States, back and forth, under very varied conditions.

QUESTION:—Do you have a reservoir for excess liquid to replace that lost by leakage, and how does it function?

ANSWER:—The tank is mounted slightly above the master cylinder so as to have a gravity feed; it feeds through several port-holes in the master cylinder and replenishes any loss due to the application of the brakes. The loss, however, is very slight.

QUESTION:—Is the band of the brake-lining continuous throughout its length or is a gap left at the rear support?

ANSWER:—We always leave a gap at the rear support, for two reasons: (*a*) it tends to cut out any dirt or foreign matter that may get into the band; (*b*) it is almost a dead point in the lining.

QUESTION:—Would the churning of the liquid cause any chemical change?

ANSWER:—None that we have found to date. I know of no reason for it.

QUESTION:—In making a turn on a wet pavement with the brakes set, is there any tendency to slide off at a tangent?

ANSWER:—Yes, if the wheels are locked. If the brakes are not applied to such an extent as to lock them the steering is normal.

QUESTION:—How often must the packing be replaced?

ANSWER:—We have never had to replace any packing on account of wear.

QUESTION:—Have you tried riveting the lining to the inside of the drum and using a plain steel band of the internal expanding type to obviate the expansion of the drum?

ANSWER:—No, we have not. To get back to the question of wear, on cups, we continue making tests at the factory; during the last 6 months we have had at least 50 cups that have withstood from 300,000 to 700,000 applications of the brake at a higher pressure than would be used in braking. This is equivalent to a life of 7 or 8 years in a car.

QUESTION:—Does the system become inoperative if a pipe line is broken or plugged up?

ANSWER:—Yes.

QUESTION:—Will not the additional margin of safety provided by four-wheel brakes be absorbed in practice by faster driving?

ANSWER:—It certainly should be.

QUESTION:—If the front wheels lock will the car skid, that is, revolve, or will it merely slide ahead in a straight line?

ANSWER:—Unless there is a decided crown or slope to the road, the car will slide in a straight line. There will be a slight side-swerve; if the car is on a crown it will tend to slide sidewise, but not pivot; the car as a whole will tend to go sidewise slightly.

QUESTION:—Is there an advantage in braking front and rear wheels diagonally in two stages?

ANSWER:—To do so would be to acknowledge that the equalization is poor. If the brakes are equalized I think it would be much better to brake all four wheels and not pay special attention to any two. There can be no advantage in braking diagonally unless the equalization is poor.

CLARENCE CARSON:—Mr. Loughead has said that he found the variation in brake-lining coefficient of friction to be from 0.20 to 0.46, I believe. It is rather hard to reconcile that statement with his other statement that four-wheel brakes have uniform equalization. I do not see how, even if he has uniform pressure per square inch on the pistons and the actuating mechanism, he can have uniform retarding of the vehicle on all four wheels, or even on two wheels, if there is that much variation in friction between lining and drum.

MR. LOUGHEAD:—I think that I supplemented the latter statement by saying that we equalized up to the band ends, and that the variable which we could not control was in the brake-lining itself.

MR. CARSON:—It seems to me that, with the greater part of the braking effort on the front wheels of the car and with such a variation in the coefficient of friction, there would be likelihood of bad "slewing" of the car, particularly if the brakes were applied on a curve. I have found that to be so on four-wheel-brake cars that I have tried. Though the cars hold to a straight course when the brakes are applied on a straight road, if the brakes are applied in making a turn, the car is liable to go wrong end first instead of head first.

MR. LOUGHEAD:—That condition does exist to a certain extent, but is within the control of the driver.

MR. CARSON:—It seems to be a problem for the brake-lining manufacturers to produce a lining with a coefficient of friction as uniform as it should have in order to get the results that are sought with this type of brake. At the present time I do not think that any of them can guarantee it.

MR. LOUGHEAD:—As a rule, a decided change in the coefficient of friction is caused by a severe case of heating. That is what I had in mind when I mentioned the extreme drop down Pike's Peak, where the brakes got very hot on account of the 7000-ft. drop in 18 miles. That did not occur with one wheel nor with another; as a rule, it occurs in all four wheels more or less.

MR. CARSON:—The Society has been conducting experimental work during the last 3 years on friction materials, in conjunction with the Bureau of Standards at Washington; and more recently I think there have been several independent investigations. To date I do not

actually occurred. We have had very few accidents. I know of no accident that has resulted in more than a dented fender; when the number of miles that I have stated is taken into consideration, I think the record is remarkable.

MR. CARSON:—A car was brought to me some time last fall, not fitted with hydraulic brakes, however, but equipped with four-wheel brakes, and the statement was made that it could not be made to skid. We succeeded in landing on a man's front lawn rear-end first while steering round a curve; so apparently they do sometimes skid.

MR. LOUGHEAD:—I should say that that was a mechanical-type brake, because it is typical of mechanical four-wheel brakes, but not so in any respect of the hydraulic brake.

MR. CARSON:—Have you had any trouble with the brake-lining's losing its gripping power on account of the lubricant's seeping by the pistons?

MR. LOUGHEAD:—We have no seepage of the lubricant at all; absolutely none.

MR. CARSON:—Have you any cars in operation around Saskatchewan, where the temperature is about 40 deg. below zero fahr.?

MR. LOUGHEAD:—I know of none. The lowest that I know of is approximately 20 below zero fahr. but the fluid we use will not solidify above 60 deg. below zero fahr. if a high enough alcohol-content, which we recommend in that extreme cold weather, is used. We have run cars under test with pure alcohol in the system and have had no trouble on account of it. Of course, it is a little harder to confine and there is more evaporation from the refilling tank under the hood.

MR. CARSON:—Does the high alcohol-content of the fluid affect the rawhide?

MR. LOUGHEAD:—Alcohol has no effect on rawhide at all.

G. L. MCCAIN:—When I wrote my question as to what economical installation could be made on a light car, what I had in mind was that the Ford stops too quickly sometimes. There must be a point at which the light car can be stopped as well as need be with brakes on two wheels. There must be some minimum weight at which it is economical to install four-wheel brakes.

MR. LOUGHEAD:—A car weighing 10 lb. and a truck weighing 6 tons can be stopped in the same distance because the coefficient of friction on the wheels retards them by a given force, so that the weight of a car has nothing at all to do with the distance in which it can be stopped, provided that there is an efficient means of braking the wheels up to the point of sliding; the light car requires it as much as the heavy one.

A. L. CLAYDEN:—Mr. Loughead said he did not know any reason for connecting brakes diagonally except to compensate for poor equalization. That was not the original idea of diagonal braking at all. The original idea of the diagonal connection was this: So long as we had a wheel on each axle rolling free, we would have either end of the car under steering control because it is only when a wheel ceases to roll that steering ability is lost. Consequently if we lock the right front and the left rear wheels, and leave the left front and right rear wheels free to roll, we shall have the locked condition on one wheel on each axle and can still steer the car almost as freely as if no wheels were locked at all.

I was able to experiment several years ago with some of the Argyll cars that were linked up diagonally or linked upon all four wheels. I also experimented a little with a hydraulic system very much like the present sys-

tem but not so well carried out in detail. I also tried four-wheel brakes with diagonal connections and all four together.

The conclusion I reached at that time was that the increased stopping power to be obtained by applying brakes on all four wheels was of much greater practical value than the theoretical advantage of the diagonal connection.

Perrot, the chief engineer of the Argyll Co., is the owner of a number of patents on the mechanical application of brakes. In 1911 or 1912 he was very strongly in favor of the diagonal connection and the Argyll car was built on that principle, with a rather complicated mechanical connection for the brakes.

I had a letter from M. Perrot only recently in which he said he had entirely given up the idea of a diagonal connection and had come round to my original view; that the plus stopping power of all four wheels was worth more than the gain from diagonal arrangement.

L. C. FREEMAN:—Mr. Loughead, I believe, made the statement that the efficiency of his transmission system is higher than that of the usual mechanical linkage. Has he any specific data to support that statement?

MR. LOUGHEAD:—The efficiency of mechanical linkage, properly lubricated, is undoubtedly in the neighborhood of 70 per cent; that is, it transmits approximately 70 per cent of the energy from the foot-pedal to the band ends but is very seldom so high after a car has been on the road from 6 to 8 months. Very few persons lubricate the brake-rod joints until something freezes or sticks and they do not operate; then they begin to drive the pins out, put kerosene on them and so forth. Very few of the cars running today have properly lubricated brakes. They are very inefficient, often not more than 50 per cent of the energy being transmitted from the pedal to the band ends. The efficiency of a fluid column, on the other hand, unless there is seepage, remains constant. The liquid acts as a lubricant on the pistons and the cup packings and is in the line at all times; the lubricant must be there if the brakes are to operate.

MR. FREEMAN:—Constant at approximately what figure? You mentioned 70 per cent for mechanical transmission.

MR. LOUGHEAD:—That is, if well lubricated. I have seen very few transmissions that would average over 60 per cent after they have been in service. An efficient hydraulic system is balanced in all four or five points, whereas with mechanical linkage, by an equalizer bar, each one is added to the other. The efficiency of the hydraulic system is about 82 per cent and remains constant.

MR. CLAYDEN:—The fact has been mentioned that several braking systems developed in England many years ago had been abandoned. Anybody who has had an opportunity of looking at them will have no difficulty in understanding why they have been abandoned.

G. W. HARPER:—Do you find that steering requires more effort at the wheel in making short turns when laterally inclined steering-pivots are used to bring the intersection of the tire and the pivot near together at the ground, than when the steering-pivots are vertical?

MR. LOUGHEAD:—When inclined steering-pivots are used the effort required to turn the steering-wheel is a little greater at very low speeds or when the car is at rest. This is due to the "scrubbing" action of the tire and the slight raising of the car. For several months I have driven a car that has an axle, the stub ends of which are set at an angle of 8 deg. from the vertical and the projected knuckle-pin center-line is $\frac{3}{8}$ in. from the center-line of the tire. This car has never shown any tendency to "shimmy" and the slight increase of steering effort at low speeds is more than offset by the greater ease of steering over rough roads and at high speeds, for most of the road shocks are absorbed by the knuckle-pin and are not transmitted through the steering-knuckle to the steering-wheel.

MR. HARPER:—How do you determine the theoretically correct position of the steering-knuckle tie-rod ball when inclined pivots are used and the consequent length, center to center, of tie-rod balls?

MR. LOUGHEAD:—The only difference between determining the position of the steering-knuckle tie-rod balls with inclined pivots and those of the conventional vertical type is that the pivot center-line is on an angle, and the location of the ball must be taken from a line parallel to this center-line. As the location of the ball is taken from the inclined knuckle-pin center-line, the distance, center to center, between these balls will depend on their vertical location.

MR. HARPER:—If the coefficient of friction between the lining and the brake-drum is subject to such wide variations as from 0.2 to 0.5 under various conditions, what is the advantage of perfect equalization in applying the operating power to the four brakes from the foot-pedal?

MR. LOUGHEAD:—If two wrongs could make a right then we should disregard the equalization of the brake-operating mechanism. As an illustration, take two cars, each of which has the same brake-lining, but in one the operating mechanism is equalized, and the other has very poor equalization. As the braking loss due to the variation in the coefficient of friction is the same in both cases, the difference in stopping ability will be proportionate to the efficiency and the equalization of the operating mechanism. In the design of brakes the variation in the coefficient of friction must be accepted until such time as there shall be a more uniform grade of lining available. When we consider that this extreme change in the coefficient of friction does not occur during more than 1 per cent of the miles traveled, and when it does occur, the change is more or less uniform at each of the wheels, then such change in the coefficient should be considered as a variation in foot-pedal pressure, rather than as a loss of equalization at the wheels.

Trolley Buses and Flexible Vehicles for Street Railway Service

By William P. Kennedy[1]

Metropolitan Section Paper *Illustrated with* Photographs

LIMITATIONS on the space in the September issue of The Journal have again rendered it necessary for a departure to be made from the usual practice of publishing a paper and the discussion following its presentation in the same issue. This paper was published last month and the discussion following its presentation is given below. As is the custom an abstract of the paper precedes the discussion so that those of the members who did not read the paper when it was printed in the September issue of The Journal can gather some knowledge of the subjects covered by reading the abstract if they do not wish to take the time to read the complete text.

ABSTRACT

THE author surveys some of the general conditions prevailing in the street-railway field and the prospective development of a new type of service, in discussing the necessity for closer cooperation between the engineers of the automotive industry and the operating organizations of the railways, the idea being to develop flexible transportation-equipment that will coordinate with the operation of present railway-transportation facilities and to promote the utilization, wherever feasible, of railway power-supply in the employment of flexible bus-type equipment in supplementing and extending railway-organization service.

Changing conditions are outlined, the influences tending toward flexible equipment are stated, and the differences of engineering practice pertaining in the railway and automotive fields are commented upon to show wherein railway and automotive engineers can cooperate.

The trolley bus is considered in some detail as being the solution of the problem, and the Mercedes Stoll, the Filovia and the Max Schiemann systems of operation are described. Present national practices of operation with various types of equipment are mentioned, and a description of dual-power bus-equipment and independent buses having electrical transmissions, with comment thereon, is included. Body and chassis requirements are enumerated, the permanency of public-service transportation and prospective street railway business is considered, and the requirements of so-called "flexible" equipment are treated at length.

THE DISCUSSION

C. C. Hecker: During the past few years we have heard and read many sweeping statements that the electric railway transportation-systems of our cities and communities have outlived their usefulness and are about to be junked and replaced by railless vehicles. Many extravagant claims have been made, usually by persons who are either grossly misinformed or who deliberately attempt to distort the facts, that buses can be operated more cheaply than electric railway cars. Curiously, some of the most distorted statements find their way into the daily press and other publications. As an example, I cite an actual instance.

Recently, there appeared in one of the most conservative and reliable newspapers of New York City a statement purporting to show that the operation of buses is so much cheaper than the operation of electric cars that the latter can scarcely hope to survive much longer. The author presented figures comparing the two types of transportation system that were little short of ridiculous. He estimated the cost of operation of a double-deck gasoline-driven motorbus at 24 cents per mile. As a matter of fact, the Fifth Avenue Coach Co.'s operating cost for the year ended June 30, 1922, was 38.3 cents per bus mile, about 60 per cent greater than the figure used by the author of the article referred to. Incidentally, the author stated that the Fifth Avenue Coach Co. was perhaps the most successful bus system in the Country and he included in his article a statement of its annual earnings, passengers carried and other financial statistics. His comparisons were made without regard to the relative seating capacities or the maximum carrying capacities of the several types of vehicle and, in general, his entire argument was almost devoid of facts or common sense.

As engineers, we are all aware that comparisons made on a bus-mile or car-mile basis must take into consideration the relative carrying capacities of the different types of vehicle. It is sometimes astounding to observe the manner in which so-called experts blandly disregard in their analyses such factors as seating capacity, schedule speeds and other important items that have a vital bearing on operating costs. For the comparison of operating costs of widely dissimilar types and sizes of vehicle, a seat-mile basis is far more accurate than the vehicle-mile. Perhaps the most accurate basis of comparison is the relative cost per passenger carried. This figure, when compared with the fare charged, tells the true story. In this connection, I point out that the cost of operation per passenger carried on the Fifth Avenue Coach Co. system, which operates under extremely favorable conditions, was slightly more than 7 cents for the year ended June 30, 1922, not including fixed charges. Obviously, this company could not exist on a 5-cent fare. Also, the weighted average cost of operation per passenger carried, for a group of 103 city electric-railway companies operating all types of car and under all sorts of operating conditions, was approximately 5¼ cents for the year ended Dec. 31, 1921, not including fixed charges. Similar figures now being compiled for the year 1922 indicate that the cost will be slightly less than this figure.

Bus-Transportation Requirements

The pioneers in the bus-transportation field had very little knowledge of the requirements of the business in which they were engaged. Most of them made little

[1] Consulting Engineer, Kennedy Engineering Corporation, New York City.

effort or else were unable to determine whether or not they were operating at a profit. In many cases the systems of accounting set up did not take into consideration all of the operating expenses, not to mention taxes, interest and customary replacement charges. The result was that many of the lines which showed a book profit actually were being operated at a loss.

Mr. Kennedy has visualized the existing conditions and recognizes the fact that no form of transportation has yet been devised that can supplant the electric railways and the railroads. The railless type of vehicle undoubtedly is destined to play an important part in the future transportation systems of our cities and communities. Its most important function, at present, as pointed out by Mr. Kennedy, is to supplement existing rail-transportation facilities in such a manner that the coordinated service will best meet the needs of the people. It is generally recognized, as Mr. Kennedy points out, that "the existing electric-railway organizations are experienced as no other agency in the utilization and operation of transportation equipment." This view has been widely accepted by state public-utility commissions, many of which have taken the position that the transportation needs of any city can be served best by permitting the established transportation company to maintain a monopoly. In other words, the best interests of a community will be served and transportation will be provided most economically by the elimination of wasteful competition and the coordination of all service under one reliable agency.

In a recent address at Detroit, Alfred Reeves, general manager of the Automobile Chamber of Commerce, said:

> Bus truck-lines have not all been successful generally because of mismanagement or because of routes that furnish insufficient return. All this means that railroad men are the proper ones to take charge of bus and truck operations, making them feeders to the trolleys and steam lines. The automotive industry is anxious to cooperate in every way that will make for each department of transportation finding its proper place, and this means efficiently serving the public

The problem before everyone interested in transportation, therefore, is the coordination of all facilities available. No conflict is being waged between the electric railways and the motor-vehicle industry; instead, the heartiest cooperation exists. Many electric-railway companies are utilizing the motor vehicle today as an adjunct to their rail systems. The trackless vehicle should serve a very useful purpose in the development of territories that heretofore have not been served by any form of transportation, and it should be especially useful in building up new territories until the time is reached when service can be given more cheaply by rail cars. Property owners and residents are assured of a permanent service when the responsibility for that service rests with the electric-railway company, and they will be encouraged to build homes and fully develop the community. It should be borne in mind, however, and the public must be educated to a realization of the fact that if service by buses is more expensive, a higher price will have to be charged for it than is charged on the electric cars.

Preferred Routes and Taxation

A large percentage of the present bus systems are operating over what can be called preferred routes. Naturally, in choosing suitable routes for the inauguration of the bus system, the operators have selected the pastures having the greenest grass. Those who advocate scrapping the railways and substituting buses must not forget that, just as soon as the buses attempt to provide service for an entire community, they will find themselves operating over many lean routes with the result that the net earnings will be seriously affected. This is a condition that practically every electric railway has had to meet. Many routes that are necessary to the transportation needs of a community, if independently operated, will not stand on their own bottoms and must be carried by the profitable lines.

Buses have not been subjected to the same burdens of taxation and regulation as the electric railways have. Most electric railways are required to pay for the paving between the rails and for a certain distance outside of their tracks. They have to pay for watering streets, for snow removal and a percentage of their gross income in state taxes; in many cases, they pay a tax to the community, franchise taxes, license fees and various other charges that put a very heavy load upon them. If the same burdens are placed upon the motor vehicle, it will be found that the railless system cannot successfully compete at the same rate of fare with the electric railway.

Properly Coordinated Service

The possibilities for cooperative work between the automotive engineers and the electric-railway managements in the development of a flexible type of railless vehicle that will meet the rigid service requirements of transportation service have been clearly expressed by Mr. Kennedy, who says: "In the street-railway organization, taken collectively, there exists a greater potential group of consumers than has ever existed in any single direction."

We all must think in terms of transportation and not of certain types of car or bus. We must bend our efforts toward the development of the most efficient vehicles to fit into a properly coordinated transportation service, if we expect to keep abreast of the ever increasing demands made upon us. An interesting point to be noted is that, in spite of the enormous increase in the ownership of private automobiles and the numerous installations of bus systems, the number of passengers handled on the electric railways in 1922 reached what is believed to be the highest level in the history of the industry, approximately 15,000,000,000.

The "store-to-door" freight-delivery business has not yet received any extensive consideration in this Country. It has been developed in a small way by some interurban electric railways through the use of delivery trucks operated to and from terminals. I believe, with Mr. Kennedy, that this field has great possibilities, if the problem is given the careful consideration it deserves.

Design Features

Designers of automotive equipment for passenger-transportation service ought to

(1) Develop designs along such lines as will permit a maximum of standardization
(2) Give adequate consideration in the designs to the inclusion of such safety features or safety devices as have proved practicable
(3) Embody, insofar as it can be economically justified, in the designs such details as will provide for the maximum comfort and convenience of passengers
(4) In the design of cars for city service, give extensive study to entrance and exit design to facilitate the rapid loading and unloading of passengers

[illegible]

H. S. [illegible]: Regarding Mr. Kennedy's statement that the Fifth Avenue Coach Co. used 10 gasoline-electric buses from 1905 to 1914 and would have continued the purchase of this type of equipment were it available and in regular production, these chassis had mounted on them what were then our standard 34-passenger [illegible] and were later equipped with a De Dion [illegible] engine of 110-mm. (4.33 in.) bore and 130-mm. (5.12 in.) stroke connected to a generator, this equipment being mounted on a sub-frame. The power was conveyed through two motors connected by chains to each rear wheel. In first speed, the motors were connected in series; for second speed, in parallel. The acceleration of these buses was sluggish, it being necessary to race the engine to high speed to excite the generator so that enough current could be obtained for the motors to get the bus under way. The gasoline consumption was very much greater than obtained with the standard mechanical-transmission buses and, although the vehicle was similar, except for the electrical transmission, its unladen weight was 664 lb. greater than that of our then standard bus.

Defects in the electrical units were often difficult to locate, even when experienced engineers were called in. Many useful bus hours were consequently lost. After following the history of all the various electric transmissions in this Country and in Europe for the past 15 years, and although substantial improvements have been made recently, mechanical transmissions also have improved and the difficulties formerly experienced with them have practically disappeared. I have no prejudice against either system and believe that the matter resolves itself into a question of which particular system will give the best practical results. In 1916, our experience and records caused us to standardize on buses with the mechanical type of transmission that we are now using. Since we started at this time to build our own equipment, the matter of production was one that was within our own control and not a deciding factor in favor of mechanical-transmission buses. Since 1916, we have tested other modern electric-transmission systems, the result has again justified our decision.

Gasoline Versus Electric Power

Mr. Kennedy seems to admit that the electric system, particularly that of the trolley bus, is not all that is needed and that he looks to the gasoline bus to help him out. From my observation, I believe that sooner or later we will discard the electric end of it and take the gasoline bus we are using today. I have visited a number of electric transportation companies that are using trolley buses in addition to the straight gasoline bus, and have been advised that the latter is by far the more efficient and economical to operate. As feeders, and for filling [illegible] needs, I believe that the former type has its field. However, the trolley car of today also has its field, and it will be a long time before the bus entirely usurps it, if ever. It is significant that five of our customers, who are [illegible] companies, are giving us large repeat orders. At least two of them have found the cost of power for the bus is very much less than the cost of electricity for the trolley car. A company in New York State is finding that the motorbus is more economical to operate than the trolley car.

C. W. Kellogg: I emphasize what Mr. Hecker has said about the attitude of the electric-railway companies to the effect that we are trying to take care of the transportation needs of the people who live in the various cities in which we operate and that we are willing to use whatever agencies turn out to be, after proper trial, the best to furnish that transportation.

Business Competition

Concerning Mr. Kennedy's statement that electric railways have grown up under non-competitive conditions, the natural inference is that, not having had the spur that competition furnishes to any business, they have been inclined to lean back, let events take the natural course and not work very hard. To the outsider that condition may seem to exist, but electric railways have had problems that have served as a spur to great effort. I think they have been just as compelling as the ordinary requirements of competition in other lines of business. For example, the 5-cent fare has necessitated much thought and study on the part of electric-railway management to make both ends meet. Competition in business causes a strenuous effort to improve service and reduce costs, and the competition the electric railways have faced has always been the effort to make a satisfactory financial showing so that, with a fixed rate of fare, they could continue to exist and take care of the rapidly growing and insistent public demands for transportation service.

What has been said about the design of equipment for carrying passengers is most important. In satisfying transportation requirements, the problem that faces automotive engineers more than any other is that of the design of a comfortable, low-center-of-gravity vehicle that the public will find comfort in using.

F. C. Horner:—I agree with Mr. Kennedy in what he says about the makeshift methods we have used in both chassis and body design of mechanically propelled vehicles for passenger transport. Our automotive engineers have either lost sight of one very important fact or else have purposely evaded it, which is that a motor truck averages between 8000 and 10,000 miles per year, whereas a motorbus averages from 30,000 to 40,000 miles, in some cases reaching 50,000 miles per year, and usually travels at a much higher speed than the truck. Therefore, disregarding the many other differences in operation of the two classes of vehicle, some of which are almost as important as the difference in mileage, we have left much to be desired in meeting the requirements of the passenger-carrying motor-vehicle operator. In this connection, I quote an extract from a paper by H. E. Blain, assistant managing director of the London General Omnibus Co., presented before the Brussels Transport Congress in October, 1922. Referring to the question of motorbus design, he said:

> It cannot be too strongly emphasized that an omnibus chassis is an entirely different chassis from an ordinary truck chassis, requiring special consideration in its springs, its weight and its efficiency, and I was specially struck, during a visit to the United States and Canada in 1921, with the failure there to realize this important point

All of the motorbus men I have talked with abroad referred to this American practice of using an ordinary motor-truck chassis with a few minor modifications as

to springs, gear ratio, and the like, with any old makeshift body for passenger-carrying work. However, even in the short time I have been home, I have noticed a very decided change for the better in this matter, and I am confident that we are at last awake to the necessity for a different policy.

The Trolley Bus

Although agreeing with Mr. Kennedy in certain respects on the matter of the trolley bus, I feel justified in calling attention to the fact that the use of the trolley bus in Europe has increased little or none since the installations made at Bradford and at Leeds, England, about 10 years ago. All of the managers of tramway undertakings with whom I discussed the matter felt that the trolley bus was unsuitable for *their* particular city. After expressing this opinion, they usually advised me to go to Bradford and to Leeds, where these vehicles have been in operation for years. In fact, I am told that Mr. Hamilton, the Corporation Tramway's manager at Leeds, was the pioneer in trolley-bus operation in England; he is probably the best informed man on the subject in Europe. Most of these tramway men stated as the principal objection to the trolley bus that it contains many of the disadvantages of the trolley car but, at the same time, lacks most of the advantages of the motorbus. The Bradford and the Leeds trolley buses have had many vicissitudes but, although they are giving satisfactory results in some respects, from the standpoint of economy they leave much to be desired, as is evidenced by the cost figures given in Table 4.

TABLE 4—BRADFORD,[24] ENGLAND, 1921 TROLLEY-BUS AND TRAMCAR COSTS

Items Per Car Mile	Trolley Buses Pence	Trolley Buses Cents	Tramcars Pence	Tramcars Cents
Expense	20.57	42	23.48	47
Traffic Revenue	13.24	27	26.56	54
Profit	....	..	3.08	7
Loss	7.33	15	....	..

[24] In Bradford, 18 trolley buses operate on 9 miles of routes.

In my opinion, the field for the trolley bus in this Country is very limited, for many reasons besides those I have mentioned but which time will not permit discussing now. I should add that a six-wheel trolley-bus is on trial at Bradford, England, and also that the City of Birmingham, England, has recently purchased several trolley buses, the preliminary tests of which I witnessed at Leeds, England, in the summer of 1922.

Dual Power Equipment

One other matter mentioned by Mr. Kennedy is that of using a tractor of the railway company, having dual power equipment, to transport goods between railway terminals and traders' store doors; in other words, to perform a "store-door delivery." This is service by a combination of straight electric-railway lines and trackless-trolley vehicles running through the streets of a city. Is my interpretation of what Mr. Kennedy has in mind correct; if so, will he explain how this would be an improvement over present methods, and also, would it reduce the wasteful traffic congestion in our city streets?

I call attention to the necessity for looking at this whole subject of transportation in the broadest possible way. For, is not the solution of the problem to be found more readily than by simply operating along conventional lines to meet the needs of today? Is it not rather that we should stand off and study the conditions from a distance so as to get the right perspective? An Englishman, who is one of the best informed road-transport men I know, wrote me a short time ago as follows:

> The solution of our traffic problems would seem to lie only in well considered town planning where work places and living places, productive centers and transport facilities will be well coordinated so as to avoid all unnecessary transport, whether of passengers or of goods, and where interdependent places will be knit together by the most direct routes

This, to my mind, sums up the whole problem in an admirable way. I am glad to say that a movement already has been started in New York City to work out the solution along the lines my friend suggests. I refer to the Plan of New York and Its Environs that is being carried on by the Russell Sage Foundation. This will be a thorough and unbiased investigation by experts; consequently, if used intelligently and honestly, the information obtained will, I believe, show us the way to make New York City a desirable place in which to live and carry on our business. At the earliest possible moment, the same remedy should be applied in many other of our cities. I think it is safe to predict that the motorbus will occupy an important place wherever passenger transport is involved.

C. J. McPherson[25]:—From my conversation with a number of representatives, the automotive industry seems to feel that the street-railway industry is not inclined to adopt the automobile as a transportation medium. From my contact with the street-railway industry, that is not true; but the fact remains that, eliminating the three best-known bus installations in the United States, few such installations, if any, are making money where they are operating as corporations. In the Baltimore installation, the cost is roughly 39 cents per bus mile, and the receipts are slightly less than 36 cents per bus mile, showing a dead loss.

A Profit-Earning Vehicle Needed

The street-railway industry must develop or secure a vehicle that can be operated at a profit. The bus apparently cannot be so operated, taking the case I mentioned as typical. If the fare is increased, the total receipts decrease, as has been proved with street cars as well as buses. This has been proved in Boston for the street railways. The trackless trolley has been tried experimentally to see if that is the vehicle. The company I am connected with has installed a large quantity of such equipment in this Country. We hold no definite brief for the trackless trolley, in spite of that. It may be the vehicle and it may not. We are not convinced that it is. The automotive industry has developed a vehicle that is the mechanical marvel of all time, the automobile; but the automobile bus and the trackless trolley apparently are not the vehicles that the street-railway industry needs, and it devolves upon somebody to develop the needed vehicle. It is you automotive engineers who should have the knowledge and the ability to produce that vehicle.

The Storage-Battery Vehicle

Mr. Kennedy mentions the storage-battery too briefly in his paper. Recently, a man very active in the sales end of the motor-truck industry said that the storage-battery vehicle had accomplished so little because of lack

[25] Sales manager of the special works department, J. G. Brill Co., Philadelphia.

of construction, but the gasoline-driven bus has not suffered on that score. If the motor-driven storage-battery truck is practicable, it offers wonderful advantages to the electric-railway industry, which has the power in quantity and at a low price. If that desired vehicle can be produced, it should be operated at a lower maintenance cost than that of the gasoline engine.

Mechanically, the trackless trolley seems to offer wonderful possibilities, but such vehicles as have been produced up to the present are mongrels, using automobile parts that are not particularly well adapted. Automotive engineers should develop parts, primarily axles, that are adapted to that service.

Supplementing a further remark of Mr. Kennedy's, if it is possible to utilize the present power that the street railways have at their disposal by means of the storage battery, it is much to be desired. The trackless trolley, due to its fixed route and its lack of range, has certain political advantages. The fact that the trackless trolley must stay on a fixed route will unquestionably render it easy to secure franchises; it is there and cannot be moved from one locality to another, particularly from one State to another, and it can be taxed and definite responsibility fixed upon it. The information that anyone would need in developing a vehicle for this service is easily obtained. The street railways are ready to give it, either direct from the individual railways or through the American Electric Railway Association. We, as equipment builders to the street-railway industry, stand ready to give to the automotive industry any information we have at our disposal. We are facing a definite engineering problem.

MR. FIELDER:—Our statistics show that the operation cost of the Fifth Avenue motorbuses in New York City is upward of 38 cents per mile. This is due to many reasons, one being excessive taxation and another the fact that we operate two-man buses for the most part. It is a substantiated fact that three of our customers, who operate single-deck buses, are doing so at a cost of from 20 to 24 cents per mile.

PROF. MORTON ARENDT:—Mr. Kennedy has emphasized, and correctly so, the need of cooperation between railway and automotive engineers and the consideration of bus transportation and auxiliary bus service by street-railway corporations. Recently, I visited Baltimore and discussed this general situation with the management of the United Railways & Electric Co. This corporation cooperates in the fullest degree. It operates standard trolley cars, buses and trackless trolleys and shows clearly that each vehicle has its sphere. In regard to what New York City has done concerning certain lines of transportation, it must be admitted that emergency demands and therefore temporary routing can only be handled by the gasoline bus, the electric bus or the gasoline-electric bus on account of their extreme flexibility. Each of these self-propelling vehicles has its advocates, but I will not discuss their relative merits now.

Crosstown Service in New York City

Because of the pending down of certain of the surface transportation lines in New York City and the growing demands for additional crosstown service, Commissioner Lorenz Whalen of the Department of Plant and Structures of the City of New York was authorized by the Board of Estimate to grant permits for the operation of bus lines by private individuals on a 5-cent fare basis, so long as the lines conformed to the regulations set up by the Department, and so long as the street-railway companies did not succeed in getting injunctions to stop their operation. The observance of these "City" regulations is made certain by the appointment of "City" bus supervisors. Complaints as regards the returns from these vehicles on a 5-cent-fare basis have not been received by the Commissioner except in a few cases, and these complaints have been satisfied by transferring buses for short periods from paying to non-paying routes and, conversely, to equalize the returns. It can also be emphasized that the so-called non-paying roads are seasonable, being very remunerative in summer. In general, these buses are operated over relatively short hauls; they are well filled and even crowded. When the haul is long, the number of passengers in and out per car mile runs high.

Staten Island Service

I feel that the ordinary gasoline bus is not the solution of transportation in partially undeveloped districts where the law does not prohibit the erection of overhead wires. On Staten Island the City has experimented with the 5-cent-fare emergency-bus and, on account of the hilly country and the relatively long hauls, the operation was abandoned because it did not pay, even before an injunction was issued against the operation of these emergency buses. In casting around for a substitute for bus operation, Commissioner Whalen became interested in the trackless trolley and, in the summer of 1921, decided to construct such a line to cooperate with the municipally operated trolley systems on Staten Island, extending transportation from Meiers Corners to Linoleumville, a distance of about 4½ miles, and from Meiers Corners to Seaview Hospital, a distance of about 1¾ miles. This line was opened to the public on Oct. 8, 1921.

On the Linoleumville line the overhead work consisted of a double-track run; that is, two groups of 00 trolley wires spaced respectively 14 in. between centers and supported by a special insulator manufactured by the General Electric Co. From Meiers Corners a single line, comprising two 00 trolley wires spaced 14 in. between centers, extends to a loop around Seaview Hospital.

After competitive bidding, the single-man-operated trackless-trolley buses furnished for this first line were built under Departmental specifications by the Atlas Truck Corporation of York, Pa. These cars weigned about 12,000 lb. empty, and were designed to have a seating capacity of 32 and a carrying capacity of 50 passengers, although frequently they have carried as many as from 75 to 80 persons. When the cars were first purchased, they were provided with trolley poles of the internally maneuverable type, but it was soon found that such construction was absolutely unnecessary and they were replaced by trolley poles of non-maneuverable type. At first, the motormen found it difficult to maintain the sliding trolley-pole heads in contact with the wires but, after the operators learned the characteristics of the road and the angle of departure from under the wires that the cars could be given, this difficulty was overcome very rapidly.

Construction of the Trackless-Trolley Cars

The first lot of trackless-trolley cars were built on 7-in. channel-iron chassis-frames with 34-in. cushion-wheels and cushion tires. Two 25-hp. motors were suspended in the center line of the chassis frame and were connected to the rear drive by a propeller-shaft that carries a propeller-shaft brake, the drive being of the

Fig. 21—One of the First Staten Island Trackless-Trolley Cars Rounding a Terminal Loop

worm-and-gear type with a ratio of 8.3 to 1. The motors use from 1.6 to 2.0 kw-hr. of current per car mile with an operating speed of between 17 and 25 m.p.h. Expanding-drum brakes are provided for the rear wheels. The propeller-shaft brake is the emergency brake; the internal expanding brake serves as a foot-brake. The motor controller is of standard series-parallel, KR type, arranged to operate with a foot switch so that the controller cannot be moved unless the foot switch is closed; this latter also serves as a "dead man's" switch. The general practice of trolley-car wiring and illumination is followed in this construction. The tread on the rear wheels to the center line was 56 in. and the height of the floor of the car from the roadbed about 37 in. The City of New York has 22 trackless-trolley buses in operation, 7 of them being the pioneer cars; they were not modified automobiles but were designed from the ground up for trackless-trolley-car purposes.

The specifications that the City issues regarding the turning radius of cars is that the trackless-trolley shall turn within a circle of not more than 15-ft. radius. Cars with a wheelbase of from 140 to 195 in. turn within such a circle very readily after the operator has had some practice

Fig. 21 shows one of the cars of the first model going around the loop at Meiers Corners. Part of the route of these cars was over a road having very poor surfacing and no roadbed foundations. This was naturally very rapidly cut-up and, as has been expressed by many who have ridden upon it, "it had the appearance of a battle field," as it was full of ruts and holes; in fact, it was almost worthless as a road. A picture of a car operating over this road is shown in Fig. 22.

Fig. 23—How the Flexibility of the Trackless-Trolley System Permitted Service To Be Maintained While the Road Shown in Fig. 22 Was Being Reconstructed

The flexibility of the trackless trolley-bus is shown in Fig. 23 wherein, after the road had become almost impassable for other purposes than trackless-trolley operation, a decision was made to reconstruct it, the trackless trolley cars swinging to one side of the highway so that the road could be rebuilt. This work comprised the entire regrading of this road, the construction of road foundation and concrete surfacing. During this work the trackless-trolley buses operated without difficulty. In the winter of 1921 and 1922 the storms put all transportation facilities on Staten Island except the trackless trolley out of commission several times. Our experience with this pioneer line has certainly demonstrated the unquestionable reliability of this type of transportation over bad roads and in all kinds of weather.

Changes in Car Construction

Certain inconveniences were observed during the operation of these cars. The bottom of the car was 37 in. from the roadway and that required two steps. Second, the tread of the wheels was not wide enough and the cars developed an objectionable side swing. We were instructed to prepare specifications for a new car that would be closer to the ground, eliminating one step, give us a broader wheel tread and bring the springs farther out so that no swaying of the car would occur. These specifications call for a car that has a 195-in. wheelbase and is of the hood type.

Fig. 22—Character of the Road over Which the Trackless Trolleys Operated on Staten Island

Residents of Tottenville, Staten Island, find it necessary from time to time to come to New York City. The distance from Tottenville to St. George is about 19 miles over the highway and probably a little more by railroad, but a round trip costs 80 to 85 cents. The municipally operated trolley-line has a branch that terminates at Richmond, a distance of about 9 miles from Tottenville. In his desire to improve the transportation facilities of Staten Island, Commissioner Whalen, after a careful survey of conditions, decided to install a trackless-trolley line to operate from Richmond, directly at the terminal of the old trolley system to Tottenville. He ordered the installation of this system, so that residents of Tottenville and intermediate places could have transportation for 24 hr. per day at a relatively close headway and low rates to St. George by way of the trackless-trolley extension operated and owned by the City and the old Midland line operated by the City under a contract

Fig. [illegible] Type of Trackless-Trolley Vehicle Used on Staten Island as Compared to Motorbus

with the Federal Court. Work was commenced in April or May, 1922, and the line was opened to the public Nov. 4, 1924. The same type of overhead construction was employed on this line as on the pioneer Staten Island line, but the type of car was changed, though the same power-plant of 25-hp. motors was retained.

The reasons for changing from the pioneer type of car shown in Figs. 21, 22 and 23, were that (a) the distance of the car floor from the roadbed was too great, (b) the wheel tread was too narrow, (c) the distance between the springs on either side of the car was too little and (d) the general appearance of the car was not aesthetic. The specifications were therefore modified to correct these features, and the trackless-trolley bus having the appearance of that shown in Fig. 24 was obtained. The interior of one of these cars, looking forward, is shown in Fig. 25. The accessibility of the motors is indicated by the removal of the trap door. The control resistances, the storage-battery and the emergency lighting-generator are located under the hood as illustrated in Fig. 26.

The car, with its long wheelbase and good springs, rides very well. It is evidently easy to reach the motors or make an examination of the brushes; also, to expose a portion of the propeller-shaft brake so that it can be adjusted from within the car. The KR type of controller is shown on the left at the operator's side, and the cash register is located at the right. These cars are not provided with ordinary rough wooden floors, but with ¼-in. battleship linoleum covering over a tongue and groove floor. We use the emergency lights because at times a trackless-trolley operator, particularly if he is inexperienced, wants to pull to the curb and take a turn at too great a safety rate, if contact with the trolley is lost, the line becomes dark. An automatic switch controls the emergency lights which gives head-lamp and tail-lamp illumination and four inside or corner lights.

After considerable bobbing the car illustrated in Figs. 24 to 26 was built by the Trackless Transportation Co., in connection with the Brockway Motor Truck Co., the Empire Bodies Co., and the General Electric Co., under the supervision of inspectors of the Department of Plant and Structures. This general design has now been adopted as standard for the City's trackless cars. Five cars are now in service, 3 being designated for the Staten Island Richmond Terrace line and 7 for City Island. This new Richmond Terrace line is supplied with power from a 600-kw. plant at Seaview Hospital by a 400-kw. 6600-volt General Electric generating-set, the power being transmitted about 3 miles by a three-phase transmission-line to a substation at Greenridge on the Arthur Kills Road over which the buses operated. This substation is a 300-kw. 600-volt automatic-substation constructed by the Westinghouse company. The operation of this line during the winter and up to the present has been most satisfactory.

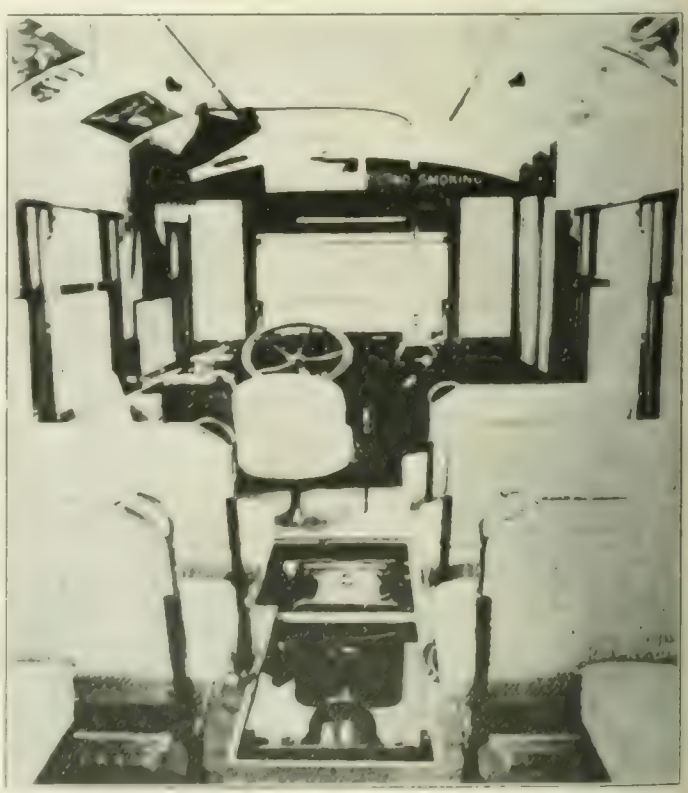
Operating Costs

Commissioner Whalen has recently made a survey of the operation, maintenance, depreciation, administration and interest charges on the trackless-trolley systems operated on Staten Island to determine whether this type of service over a total of approximately 16 miles of road or from 28 to 30 miles of line is cheaper than that obtainable by gasoline buses operating with the same schedule and with the same number of cars. It was found that, taking all of the above items into account, the trackless trolley could be operated at a cost of 25.6 cents per car mile; whereas, the gasoline-bus operation would have cost 33.9 cents per car mile.

If the trackless-trolley buses were increased in number with a corresponding increase in the gasoline buses, the difference would be even greater, because the overhead construction which costs about $6,500 per mile of route becomes a smaller and smaller factor in the computation of the fixed costs.

The "Permanency" Factor

Trackless-trolley systems have a value over motorbus lines for undeveloped-locality transportation which cannot be directly expressed in dollars and cents per car mile, though it is made very apparent in "realty-tax" returns. This is the effect of the idea of *permanency*



The Interior View Looking Forward in One of the Cars Illustrated in Fig. 24

Accessibility of the Motor by Removing a Trap Door Should be Noted; Also the Position of the Motor Controller, the Steering-Wheel and the Registering Fare Box

resident in the trackless-trolley overhead-construction. The valuation of real estate along the Staten Island trackless-trolley lines has increased enormously. That the psychological effect obtains can be emphasized further by calling attention to the experiences of the United Railways & Electric Co., at Baltimore. This corporation operated a 7-mile motorbus-line in the outskirts of the city and gave excellent service; but, as no building activities followed, the line was abandoned. Later, at the request of the Public Service Commission of Maryland, the company constructed a trackless-trolley line over the same route and, within 3 months, marked building activity commenced. Eighty homes were erected and real estate increased about 20 per cent in value.

Trackless Trolley Advantages

We have found that the trackless trolley accelerates more rapidly, more uniformly and with greater comfort to the passengers than the gasoline bus can possibly do. We find it takes the hills, which are very pronounced on the Tottenville line, with ease.

The advantages of the trackless trolley over those of the gasoline-driven bus are

(1) Lower operation expenses
(2) Unlimited heat
(3) Unlimited light
(4) Less noise when starting or accelerating
(5) No gas fumes
(6) Better hill-climbing power

I feel that Commissioner Whalen has shown considerable vision in his selection of the trackless trolley as the means of transportation in the lightly populated sections of Greater New York City; and further, that it must be very seriously considered by all railway officials who wish to extend their systems without encumbering themselves with both excessive fixed and operating costs.

Ethelbert Favary:—The advantages of the gasoline motorbus have scarcely been mentioned and the advantages of the trackless-trolleys and electrically operated cars have been overemphasized. The trackless trolley may be more economical and more efficient in outlying districts, but it is impractical for city use. I also disagree with Mr. Kennedy's statements that

> Street-railway organizations ..... are qualified ..... to render public service, modified wherever necessary to meet changing demands
>
> Ultimately, public transportation must certainly remain in their hands
>
> The vehicles which would best serve these purposes would be those that could utilize partly, if not entirely, the power supply and distribution system available ..... existing within the street-railway organizations. By such means existing properties representing large investment can be preserved.....

These views may do incalculable harm to motorbus transportation-systems. For instance, the suggestion has been made that the street-railway companies in New York City receive franchises to run motorbuses along the different avenues instead of their surface lines, since the traffic could be increased one-third by such a change. The surface cars, being in the middle of the street, delay all fast-moving traffic, while motorbuses can receive or discharge passengers at the curb. Many other advantages are provided by motorbuses, and many disadvantages are inherent in electric surface-lines, but greater comfort and speed are furnished by the motorbus.

Motorbus Lines in New York City

The capitalization of the street-railway companies is more than $500,000 per mile. According to Commissioner Whalen, the bus lines now in operation on New York City streets can be equipped at an average cost of $22,800 per mile, including the motorbuses and garage equipment. Even with this figure doubled, it would still be less than one-tenth of the outlay of the street-railway companies per mile of line. Six per cent on $500,000 is $30,000; this is the amount the lines would have to earn per mile, in addition to their running expenses, to pay the interest charges alone.

To run a motorbus line with such a heavy initial-handicap means either inferior service or an increased fare, or both, to make the line profitable. The interest charges per mile of street railway alone is sufficient to renew the entire bus equipment every year; hence, a new company relieved of that heavy burden to begin with, could

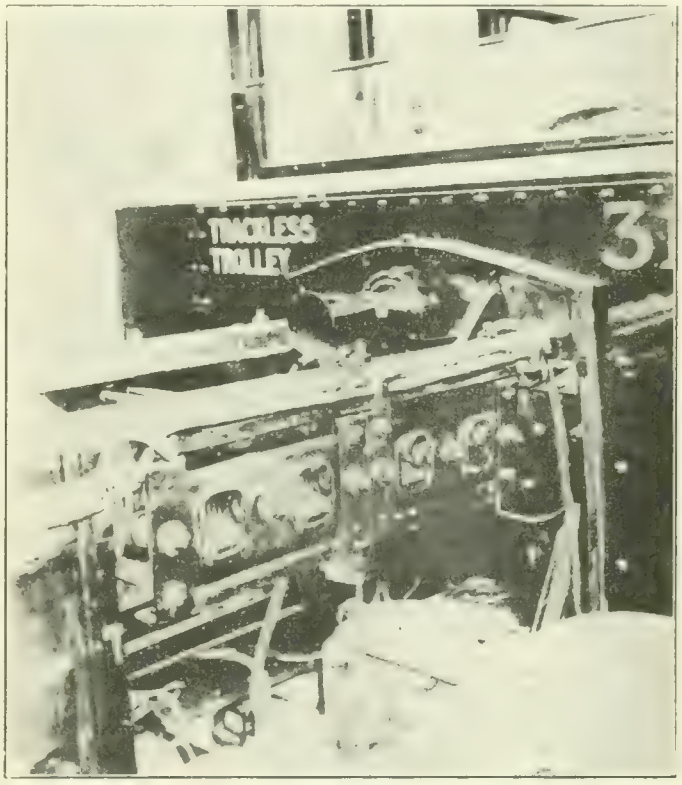


Fig. 26—How the Control Resistances, the Storage-Battery and the Emergency Lighting-Generator Are Placed under the Hood at the Front of the Vehicle

give better service at less cost. No doubt these conditions obtain in many other cities and, while it is advantageous for the street-railway companies to run trackless-trolleys in outlying districts, they may make failures even of these, due to their over-capitalization.

The argument has been advanced that, on many lines, the motorbus does not give such an assurance of permanent service as the electric street-car lines and therefore, property values do not increase as they do along street-car routes. Examples are cited in which motorbus lines have been discontinued and in which many others are losing money. Why cannot motorbus companies be as responsible as the street-railway companies? As soon as our cities are prepared to give motorbus companies regular franchises over good routes, such as New York City avenues, these companies will be as responsible as the street-railway companies, if not more so, and will not be losing money. Many motorbus lines failed because the street-railway companies had the franchises over all the good lines, while motorbuses only had franchises over

those lines where the traffic was slight or where the street-railway companies had abandoned service, due to the paucity of traffic. As soon as motorbus companies are given proper franchises, they will become responsible and their service can be made just as efficient as that given by the Fifth Avenue Coach Co.

Motorbus Economy

From Mr. Kennedy's figures, the operating expense of the trackless trolley is less than that of the motor omnibus when the interest rate from capitalization is not considered. While this may be true today, the motorbus is a comparatively new product and, due to improvements that are being made continuously, we can expect a more efficient utilization of fuel and a reduction in the operating and maintenance costs. Maintenance can be reduced by lessening the impact due to road shocks, and this can be accomplished by improving the spring suspension and the tires.

To show the difference in the weight and the cost of a chassis when equipped with pneumatic tires, to reduce impact and allow greater speed, and solid tires, two examples of well-known makes given in the Handbook of Automobiles, published yearly by the National Automobile Chamber of Commerce, are

1½ ton chassis equipped with pneumatic tires; price $2,887; chassis weight, 2930 lb.; gross weight, 6080 lb.

1½ ton chassis equipped with solid tires; price, $7,450; chassis weight, 5700 lb.; gross weight, 12,000 lb.

Because solid tires are used on the second chassis, the entire construction must be more substantial to resist the greater road impacts, the chassis weight is more than double and the cost is more than treble. In addition, the operating costs are necessarily higher.

Joseph A. Anglada:—Certain fundamental reasons should cause the automotive engineer to pause in his intensive efforts to improve the gasoline powerplant further and consider whether he is directing his energies to the most sensible solution of the problem of providing public vehicles for the transportation of passengers at the lowest cost. The function of the engineer is not only to apply the achievements of the arts and sciences for the benefit of the public, but also to do so in a way that will conserve natural resources and produce results at the minimum cost. He should not merely provide a technical solution of the problem but a commercial one. This raises the question whether, in the field of the motorbus, the horizons of the engineer and the business man have not been clouded sufficiently by their close familiarity with the internal-combustion-engine type of vehicle to cause them to lose sight of the applicability of the electric vehicle to this arduous service.

If the broad unbiased mental outlook is preserved, the outstanding features of lower operating cost, long life, low maintenance cost, simplicity, cleanliness and safety of the electric vehicle are recognized as being essential to providing the best motorbus service from the standpoint of the public and the operators of the service. It may be argued that someone at some time has tried electric vehicles in this service without success, but an investigation of the cases will show that, under the same conditions, any other type of vehicle would not have succeeded.

Severity of Motorbus Service

A survey of the conditions under which motorbuses operate in urban districts reveals a close similarity between electric-street-car service and motorbus operating conditions. The frequent stopping and starting of the vehicle, as often as 15 times per mile traveled and averaging 6 times per mile, imposes a service on the propelling and speed-controlling machinery of the vehicle that exceeds in severity that due to continued high-speed operation on good roads. Compared to the electric vehicle, the gasoline-engine vehicle is not, nor in the light of present knowledge can it be, adapted to withstand the high duty of motorbus service as efficiently as the simpler and more reliable electric vehicle. For proof, it is necessary to consider the few gasoline-motorbus installations extant that have made money for their operators over a period of years and to ascertain the reason. Analysis will reveal that, for the first year or so, the gasoline equipment operated satisfactorily because it was new. After the second year, the depreciation on the equipment, due to the nature of the service and the high-speed performances indulged in by the drivers, increased greatly, while the necessity for adjustments and repairs became annoyingly important. After a period of from 3 to 5 years, the maintenance charges became so great as to prohibit the safe use of the vehicles for public service by responsible organizations. The result was that the so-called outlaw or jitney operator entered the field and the service suffered still further.

Operating electric street-cars in the dangerous physical condition existing in many motorbuses would not be tolerated by the public or the operating companies, and when it is known that the electric street-cars are from three to five times as old as the gasoline vehicles and have cost decidedly less to maintain during their life, it will be conceded that electric propulsion of passenger-carrying vehicles operating on tracks in city service possesses fundamental advantages that can be applied to vehicles operating on rubber tires.

Long life, low operating and maintenance costs and ease of control are the fundamental advantages of electric vehicles, whether of the storage-battery, trackless-trolley or self-charging type. In addition, flexibility of the chassis construction permits great passenger accommodation with a low floor-level in a simple inexpensive chassis having a short wheelbase and consequently a short turning radius; also, with the body overhang beyond the axles reduced to sensible proportions.

Arthur J. Slade:—Supporting Mr. Kennedy's contention for an analysis of passenger-transportation problems in given instances and the production of suitable equipment to meet the specific requirements of each installation, some European experience is cited.

In France, the Paris, Lyons & Marseilles Railway has provided passenger buses and touring coaches by which tourists may continue their excursions beyond the rail terminals; for example, through the French Alps and, more recently, along the northern coast of Africa through the French colonial possessions. These extensions not only produce revenue in themselves, but bring added passenger traffic to the railroad. In Paris, the subways, the trolley lines and the buses are operated by a common transportation company under municipal supervision. The subways run to most of the old-city gates; the trolleys operate largely outside the city proper, serving the suburbs but running into convenient central locations within the city. In the most congested districts the buses, operating on the zone-fare system, serve the short-haul traffic, the routes being laid out, changed or extended to meet the requirements of all localities from both the viewpoint of revenue and that of public service. The three mediums of transportation are run in co-operation, not in competition. At present, trolley-bus

extensions are being installed which may eventually become trolley railway-lines, as the suburban growth of Paris is increasing very rapidly. Gasoline motorbus routes are being added and extended as the area occupied by the old-city fortifications, which are being razed, becomes occupied by apartment houses and dwellings. The passenger-transportation problem is being handled broadly and comprehensively, without prejudice in favor of one medium over another. In certain parts of Paris the traffic congestion has attained serious proportions and, in the summer of 1922, the subject was discussed at some length in the newspapers. In this connection, some of the details of the latest Paris buses, as described in a recent issue of a leading French engineering publication,[27] are interesting.

The Six-Wheel Motorbus

Regarding the six-wheel motorbus, this publication suggested, as far back as 1904, means whereby heavy-duty vehicles could be made to carry heavier loads on six wheels than on four. This idea has been taken up by the transportation company of Paris with the purpose of increasing the carrying capacity of the motorbuses that operated in the center of the city, the increase in the congestion of passenger transportation having led to this study.

On the trolley lines, cars hauling trailers offer a combination seating 100 passengers and even more at peak loads. The motorbus, which is particularly popular, has only been able to carry 38 passengers. While it would be possible to mount an upper deck to increase this capacity, as was the former practice with the horse-drawn omnibuses and the earlier motorbuses, and notwithstanding the custom in England, where the double-deck motorbuses and trolley cars are generally used, the double-deck arrangement has been definitely discarded in Paris for the omnibuses as well as for the trolley cars, principally on account of the delay that this arrangement requires for the entrance and the departure of passengers, certain trolley-car lines in the suburbs being the only exceptions.

Until recently, the omnibuses with a capacity of 38 passengers have been satisfactory, but the necessity of increasing the capacity has induced the study of a solution involving an increase in the body length to be carried by three axles. One of these buses with six wheels and a capacity for 48 passengers has already been placed in experimental service on the line from the Madeleine to the Bastille, which follows the grand boulevards, and an equipment of 50 more such vehicles is now under construction.

The new motorbus has a total length of approximately 34 ft. and an overall width of approximately 7½ ft. The three axles are unequally spaced. The forward wheelbase is approximately 14 ft. and the rear wheelbase approximately 7 ft. The front and the rear wheels are steering wheels, those in the center of the vehicle not having steering functions. All of the wheels are 38 in. in diameter, the forward and the rear wheels having single tires and the intermediate wheels dual tires.

In the case of a vehicle having two axles, the distribution of the load on the wheels is automatic regardless of road irregularities, which is not possible in a six-wheel chassis without recourse to a special construction, consisting of what may be described as a balancing lever joining the forward ends of the rear springs to the rear ends of the intermediate springs. This balancing lever pivots on an axis carried by a bracket attached to the chassis. With this arrangement, the applied weight of the chassis on the springs is distributed automatically, regardless of the relative positions of the wheels themselves.

By a predetermined location on the center axle, the weight on the driving wheels can be proportioned, which is a valuable consideration in the improvement of the tractive effect of the driving wheels. An added advantage of this balanced suspension is to reduce the vertical displacement of the chassis, reducing shocks and tending to diminish the wear on both the vehicle and the pavement. Two brakes, one on the transmission shaft and the other on the intermediate or the driving wheels, are provided. The engine of the new motorbus is of the same type as that employed on the four-wheel buses of the company, and the other general features of the powerplant are similar to those previously in use.

The forward and the rear wheels are steering wheels, and these four wheels, which are mounted on conventional steering-pivot axles, are connected together with lever arms and rods to turn, in steering, so that their radii converge at a central point that is also on the axis of the intermediate driving-wheels. Inasmuch as the rear steering-wheels, to accomplish this result, do not turn to as great an angularity as the front steering-wheels, a difference of leverage is introduced in the steering connections. The six-wheel vehicle has less tendency to wabble or depart from the straight line than the four-wheel vehicle, and greater steering stability results.

The article in *Le Genie Civil*[27] is illustrated by views showing the overall dimensions, the steering linkages, the spring-suspensions and the turning radius, and it is interesting to note that the clearance circle for the front end of the vehicle has a radius of approximately 28 ft. and the rear end of the vehicle 27 ft., while the turning radius of the inner of the driving wheels is approximately 16½ ft. When empty the total weight of the omnibus is approximately 16,000 lb., which is a little more than 300 lb. per passenger or very much less than that per passenger on the trolley cars, which is nearly double. On the latest trolley cars, the weight per passenger has been reduced to slightly more than 500 lb. Nevertheless, it is hoped to reduce the six-wheel-omnibus weight on a new model that is now being designed for either a gasoline-engine powerplant or an electric motor with a double trolley to about 260 lb. per passenger.

Except for its greater length, the body construction is arranged similarly to that of the former type of bus. The forward or first-class compartment seats 20 passengers instead of 16, and the second-class compartment seats 20 instead of 12. On the other hand, the platform carries only 8 standing passengers instead of 10. This reduction in the platform capacity is due to the narrow shape that has been given to the platform to increase the clearance on turns. The new bus, therefore, carries 48 instead of 38 passengers. In all the Paris buses the seats are arranged so that about an equal number face forward and to the rear. Standing passengers are not permitted inside, but only on the platform. Largely increased carrying capacity would be possible if the aisle space within the body might be occupied by standees.

Finally, a further improvement recently proposed is the replacement of the solid by pneumatic tires, which will unquestionably increase the comfortable riding qualities of the vehicles. An omnibus equipped with pneumatic tires has been put on trial, and the results obtained by the tests will decide whether it is advantageous to adopt pneumatic-tire equipment. The foregoing installa-

[27] See *Le Genie Civil*, Dec. 30, 1922, p. 605.

[illegible] argument presented in Mr. [illegible]'s paper in favor of coordination of railway and automotive transportation.

W. F. Kenney.—Mr. Fiddler mentioned reasons why the gasoline-electric buses on Fifth Avenue were not continued. I wish to point out that these gasoline-electric buses were built at a time when there were few gas engines to choose from. In fact, the sources of supply were so limited that special engines had to be built for them. These engines were not at all as satisfactory as they might have been and were afterward superseded by De Dion engines.

About the possibilities of the gasoline-electric bus and its being continued, I quote part of a letter dated April 17, 1919, from R. M. Meade, then president of the Fifth Avenue Coach Co., in which he covers this subject as I have stated it.

> Confirming what I said to you today, if the engines of the gasoline-electric buses had been as good as the De Dion engines, we would not have gone abroad for the 25 chassis we recently ordered.
>
> This statement is made in the light of the results obtained from the experimental installation of the De Dion engine in bus No. 156, as the performance of that bus shows that the electric-transmission feature is a complete success. At the time we ordered the 25 chassis referred to, we had not had the benefit of that experiment.

This indicates clearly that if he could have got gasoline-electric buses having proper engine equipment at that time, he would have continued their use.

Mr. Horner pointed out that no progress has been made in trolley-bus installations in England in recent years. The conditions of operation over there are not such as we have to contend with, in the changing conditions here at present. The tendency to put out new vehicles is indicated in what the Associated Equipment Co. has done in developing its new-type trolley-bus equipped with a single motor. The conditions with which the street railways have to contend at present in this Country make the situation entirely different from the one that has existed in England; consequently, under these conditions, an opportunity exists to develop the trolley bus much more effectively than the opportunities in England afford.

Another point questioned had reference to the feasibility of the street railways rendering service in the transfer of freight and particularly such services as is exemplified by the store-door delivery, whether such service would produce congestion of traffic or whether a good business opportunity warranted this or not. My recommendation in this direction was to show the possibility that exists for the street railways if they want to go into the freight-handling business. In making that recommendation I naturally do not have in mind such cities as New York or the larger cities where perhaps the street railways would not be justified in entering into that phase of business. It appears that in the numerous minor cities throughout the Country, such as Dayton, Ohio; Rochester, N. Y.; Columbus, Ohio, and dozens of other such places where store-door delivery has not the conditions of congestion that exist in New York City, it would be feasible for street railways to go into that business for profit.

Mr. McPherson asked why storage-battery equipments were not recommended. Nobody is a stronger advocate of the use of storage-batteries than I have been, because I have been responsible for putting more of this type into use than many other engineers have done. I am in favor of the storage-battery, but it is a hard job to sell it. Nobody wants to take up the burden of it. Even the storage-battery companies do not, and neither do the vehicle builders; therefore, I do not feel justified in shouldering such a large proposition myself. But I firmly believe that the electric-storage-battery vehicle, rationally applied, would be the most economical one that a street-railway company could use, especially when it has cheap power, and this is substantiated by what Mr. Anglada has said.

BUSINESS FORECASTING SYSTEMS

IN attempting to forecast the trend of business, two fundamental principles are involved. The so-called modern forecasting system aims to make reliable estimates of the future by applying the theory of causation. Predictions are based upon the assumption that, since economic phenomena are responsive to fundamental laws, therefore approximately similar causes should produce similar results, interpretations of possible results being based upon past experience. The method has proved to command it; and its value is of course dependent, to a large measure, upon the accuracy of the statistical material used and the degree to which similar material of the past is available as a basis for making [illegible]. As our information and statistics become more accurate, and as more experience in interpreting them is acquired, the greater will be the value of studies of this [illegible].

The cash-market method, on the other hand, follows a different principle, which has also many features to commend it. Its theory is also to predict, by reflecting in a definite manner, the dominant opinion upon which business men are acting after important decisions have been made. Thus, to the extent that current business opinion makes a proper estimate of the future the market should tend to anticipate conditions.

Both methods of attempting to predict the future of business appear to have merit; neither, however, has achieved for itself a place that makes it infallible. The factors influencing the trend of business conditions are as complicated and difficult to appraise as human nature itself. Economic factors are responsive not only to certain basic, physical and so-called economic laws but are also modified to a great extent by the injection of psychological factors of which we as yet have little understanding. For this reason great care and judgment must be exercised in dealing with economic data that aim to forecast the future. No "rule of thumb" method has yet been found that can be substituted for individual research, judgment, and hard-headed business acumen.—H. F. Boettler, First National Bank, St. Louis.

Illumination Diagrams for Showing Head-Lighting Device Performance

By F. H. Ford[1]

Mid-West Section Paper *Illustrated with* Photographs and Charts

INSTEAD of representing light intensity by lines to indicate photometric values the author recommends an arrangement for denoting the intensity by varying degrees of tint on the surface of a chart that is supposed to represent the roadway. In the opening paragraph the thought is brought out that present-day automobile lighting equipment is not designed in such a way as to make its performance a selling feature and the several reasons why the efficient distribution of light on the road has been overlooked are pointed out, emphasis being laid on the fact that the average car-designer is not an illuminating engineer, and that even if he did wish to use the best light available on the car he would have to make personal tests of the devices under all conditions of night driving before being in a position to recommend the most efficient head-lighting device.

The method of comparing devices by illumination charts that illustrate the performance of head-lighting devices is described, and charts from four typical specimens chosen from the many that are on the market are reproduced to show that while the light from each of the devices does not exceed the glare limit above the level of the head-lamp and is at least sufficient to meet the minimum driving-light that the law demands below the level of the head-lamp, a marked difference in the efficiency of these equally legal devices will be found. The construction of the devices for which the road illumination charts are reproduced is described.

Tabular data show the report of a test of the candlepower distribution from the combined beams of a pair of standard head-lamps as directed toward various points on a vertical screen located 100 ft. ahead of the test lamps. The outlining of areas of equal illumination is described at some length, the text being supplemented by diagrams and tables.

THE lighting equipment of present-day automobiles is not designed in a way that makes its performance a selling feature. True, various attempts have been made at the modification of the cone-shaped beam of light that comes from an electric bulb within a parabolic reflector by glass fronts or lenses, and there have been attempts to use specially shaped reflectors that deviate from the true parabola. These modifications, however, have been largely made with a view to eliminating glare, and if the thought of improving the distribution of the light on the road has been present, it has, judging from the results obtained, been a secondary consideration.

Efficient distribution of light on the road has been overlooked for several reasons. The average car designer is not an illuminating engineer. He does not design his own head-lamps. If he has a hobby, it is more likely to run to some item of mechanical equipment or to body design. Head-lamps are to him a necessary evil, like a kit of tools or a horn or spark-plugs, something to be bought as cheaply as possible and consequently within the jurisdiction of the purchasing, rather than the engineering, department. What if the light is not so good; cars do not often have their driving lights compared. If the lamps look good on the outside and if they look sufficiently legal so that dealers will not enter a protest, nothing more is necessary.

Furthermore, even if the car designer realized that exceptionally good driving-light might enhance the value of his car, and if he had made up his mind that he wanted the best light available, he would have a hard time making a choice without personally testing dozens of devices under all conditions of night driving. He can easily eliminate those that are illegal by referring to the lists published by the various States. From these lists he could even determine which device was the most efficient from the standpoint of stopping glare. But nothing has been published to show the comparative lighting efficiency of head-lighting devices.

If it were a case of lighting a factory or an office, no trouble would be experienced in choosing proper equipment by comparing the illumination charts that are available for industrial lighting fixtures. But despite the importance of good driving-light to the comfort and safety of the driver, no data more useful than the claims of manufacturers have been published.

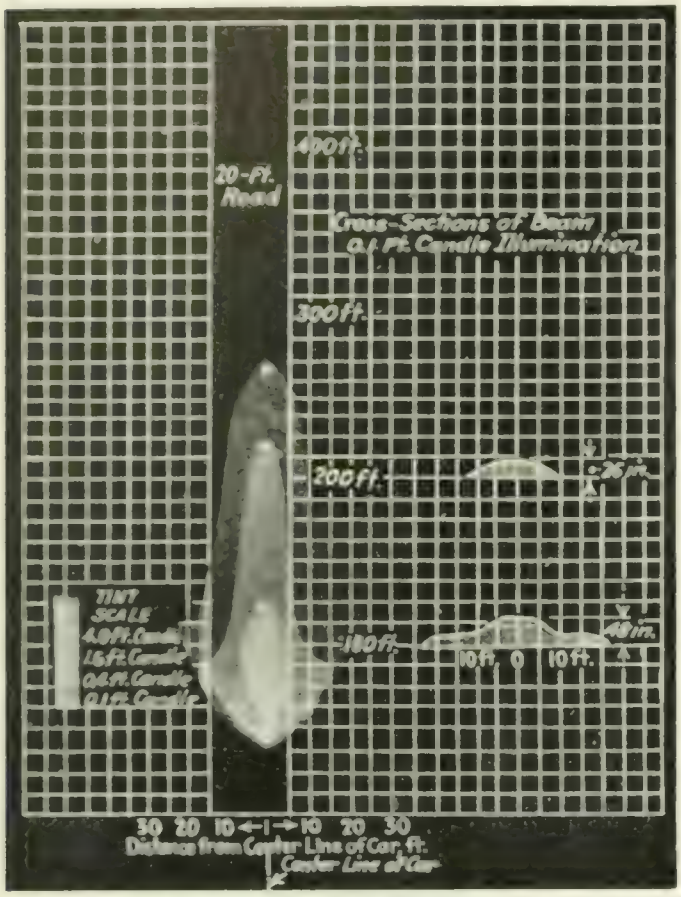
Use of Illumination Charts

In this paper we shall show a method of comparing devices by illumination charts that illustrate the performance of several typical specimens chosen from the many that are on the market. It should be noted that the light from each of these devices is perfectly legal; that is, it does not exceed the glare limit above the level of the head-lamps and it is at least sufficient to meet the minimum driving-light that the law demands below the level of the head-lamps. The difference in efficiency between these equally legal devices will be apparent at a glance. The devices used to illustrate this method of comparing the efficiency of driving-lights were selected because they represent the four types of head-lamp equipment most commonly used as standard by car builders.

Devices Nos. 1 and 2 are both lenses designed for use in a head-lamp in which the lamp filament is set at the point in the reflector that will give a beam of the smallest possible diameter. With this adjustment of the filament and without the lens in place the beam will diverge slightly from the true cylindrical form, because it is compounded of diverging rays from that part of the filament behind the reflector focus, of nearly parallel rays from that part of the filament near the focus and of rays from the part of the filament ahead of the focus that first cross over and then diverge.

With an unmodified beam of this sort, the light would

[1] A.S.A.E.—Engineer and manager of head-light lens department, C. A. Shaler Co., Waupun, Wis.



[illegible] projected to a great distance. It is the searchlight principle, excellent for spotting an object far away, but unsuitable for lighting a road, because the beam is too narrow and would leave the sides of the road and the immediate foreground in darkness. Furthermore, this beam, unless tilted down very sharply, would give an objectionable glare, and then its value for distance use would be lost.

Device No. 1 bends the beam downward by horizontal prisms that cover the entire opening in the head-lamp. These prisms are proportioned so that, in this particular device, the most intense part of the beam is deflected downward until it strikes the road about 50 ft. ahead of the car when the head-lamp itself is pointed so that its axis is parallel to the road. The width of the lighted area on the road is increased at the expense of its length by vertical cylinders, because the lens that spreads the light sideways gives the beam cross-section the form of a modified ellipse.

The illumination diagram for device No. 1, reproduced in Fig. 1, shows that the lighted area is widest at a distance of about 100 ft. in front of the car and narrows rapidly beyond that distance. The maximum range of the 0.1 ft-candle illumination is only about 250 ft. The diagram showing the cross-section of the beam also shows that the depth of the light on the road decreases rapidly as the distance from the car increases; in other words, that the top of the beam slopes downward so that at 250 ft. ahead it would be difficult to detect an object extending 1 ft. above the road. This extreme slope of the beam is made necessary by the fact that the unmodified beam from the reflector is a compound beam, composed of divergent and convergent as well as parallel rays, and to eliminate the glare of the former, all the rays are bent downward, as a group. To separate the different kinds of ray is impossible, and all must be deflected downward together.

In device No. 2, for which the illumination diagram is reproduced in Fig. 2, no provision has been made within the lens itself for bending the beam downward to comply with the glare limits set by Illuminating Engineering Society specifications. This must be done by tilting the head-lamp itself, a thing that is not often done because of its unfortunate effect on the driving light.

Devices of this type are provided with only vertical cylinders, which spread the light laterally and, in general, spread it wider than do devices of the design of No. 1. This greater lateral spread has the effect of making the modified beam into a comparatively thin sheet of light. Aside from the greater width of the lighted area, the distribution of light from device No. 1 is very much like that of No. 2. The slight difference shown in the diagram is due largely to the fact that the prisms of the No. 1 device gave the beam a little more tilt than was necessary to avoid glare, while the beam from No. 2 was tilted just enough to make it meet the Illuminating Engineering Society's requirements.

With both types of device the brightest light is near the axis of the beam, and when the beam is directed downward sharply enough to comply with the glare limits it causes an over-illumination of the road about 50 ft. ahead of the car, directly in the driver's line of vision.

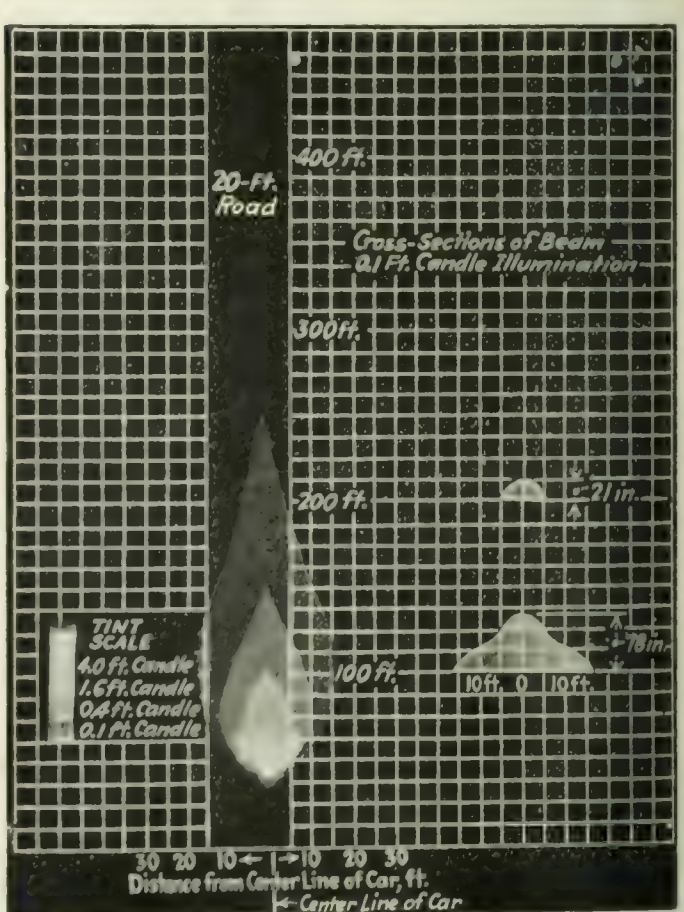


Fig. 2—Illumination at the Road Level from a Device That Is Designed for Use with the Lamp Filament at the Reflector Focus and with the Head-Lamp Axis Tilted 12 In. at 25 Ft.

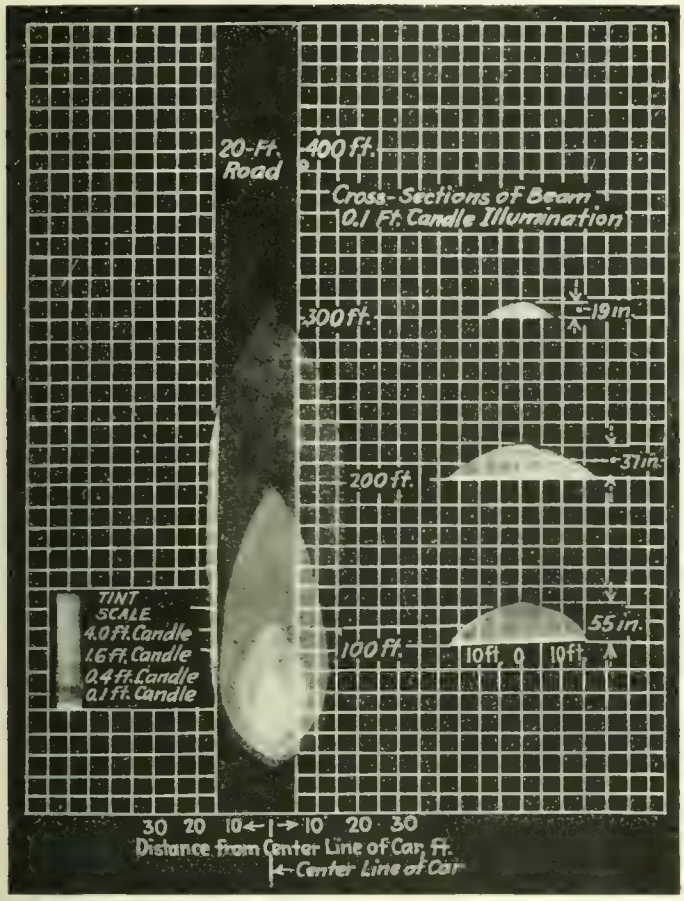


FIG. 3—A DEVICE MADE UP WITH A SPECIAL REFLECTOR AND A PLAIN COVER GLASS ILLUMINATED THE ROAD AS SHOWN IN THIS DIAGRAM

Device No. 3, the illumination diagram of which is reproduced in Fig. 3, illustrates one type of specially formed reflector that throws a beam having an elliptical cross-section, instead of a round beam, as does the parabolic reflector. The light is distributed in practically the same manner as with lenses such as No. 1 and No. 2, except that the beam is a little brighter in the center. The total width is somewhat greater than can successfully be obtained by using vertical cylinders to spread out the highly concentrated and nearly cylindrical beam from a standard parabolic reflector. The great accuracy required in forming the surfaces of a reflector of this type and in locating the filament within it seem to present a problem in manufacturing it in commercial quantity.

Device No. 6 is a type of lens designed for use with a head-lamp having an adjustable filament back of the focal point of a regular parabolic reflector. When the filament is in this position all the rays will diverge from the axis of the beam. The intensity is greatest near the center of the beam and decreases toward the outside. The unmodified beam is a fairly wide-spreading cone with the brightest part near the center. All the light from the lower half of the reflector is directed below the level of the reflector by the reflector itself. As it is unnecessary to tilt this part of the beam to avoid glare, the beam can be used to full advantage for lighting distant parts of the road. The brilliant part of the beam is allowed to shoot forward parallel with the road instead of being aimed downward.

Since the most intense part of the light in the lower half of the beam is projected at the smallest angle below the level of the head-lamp, the top of this part of the beam is the brightest, and this bright part intercepts the road farther ahead of the car than do the weaker parts of the beam. The less intense light, which is projected more sharply downward by the reflector, intercepts the roadway nearer to the car. By means of vertical prisms or cylinders the lateral spread of this part of the beam can be increased or decreased as may be desired. The light from the upper half of the reflector can be redirected below the level of the head-lamp to avoid glare and to give additional illumination at points of the road that are not sufficiently illuminated by light from the lower half of the reflector.

The illumination diagram for device No. 6 is reproduced in Fig. 4 and shows the effective distribution of light that can be obtained by redirecting the light from a divergent beam by suitable prismatic elements. In this particular device the light from the lower half of the reflector is used to furnish the illumination straight ahead in the path of the car. The light from the upper half of the reflector is divided and is directed toward both sides of the road, furnishing illumination along the edges for which a spotlight would ordinarily be used and adding to the width of the illuminated area for 100 ft. ahead of the car. This additional illumination is to the side of the driver's direct line of vision so that it does not interfere with his ability to distinguish objects at a distance.

A comparison of the illumination diagram for the four devices shows that no inherent property is possessed by either lenses or reflectors which makes either group the only solution of the problem of securing good driving-

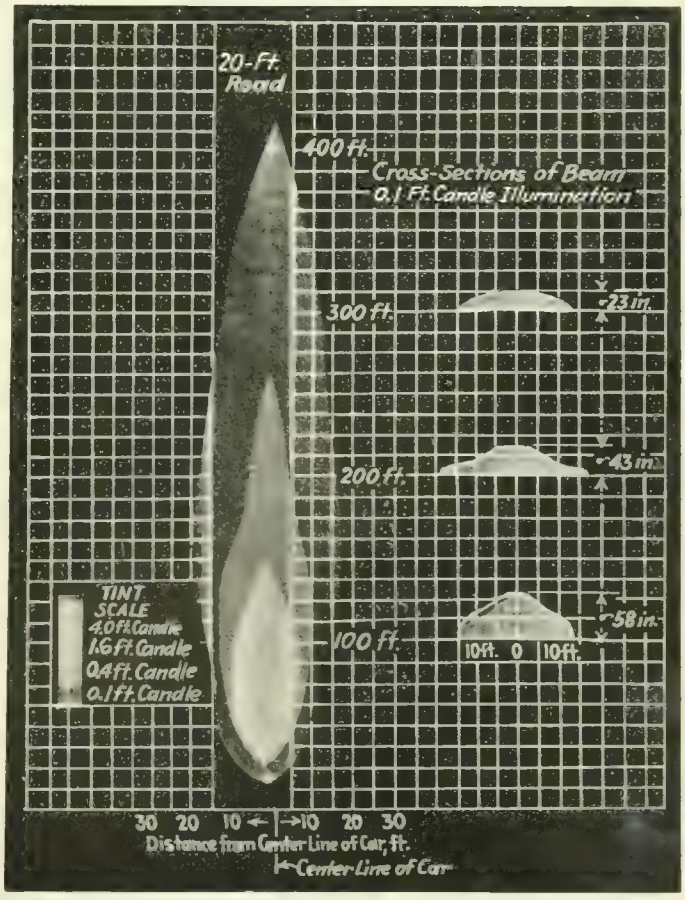


FIG. 4—DIAGRAM SHOWING THE ILLUMINATION AT THE ROAD LEVEL FROM A DEVICE THAT IS DESIGNED FOR USE WITH THE LAMP FILAMENT BACK OF THE REFLECTOR FOCUS

TABLE 1—CANDLEPOWER DISTRIBUTION AS AT 100 FT. FOR DEVICE NO. 1

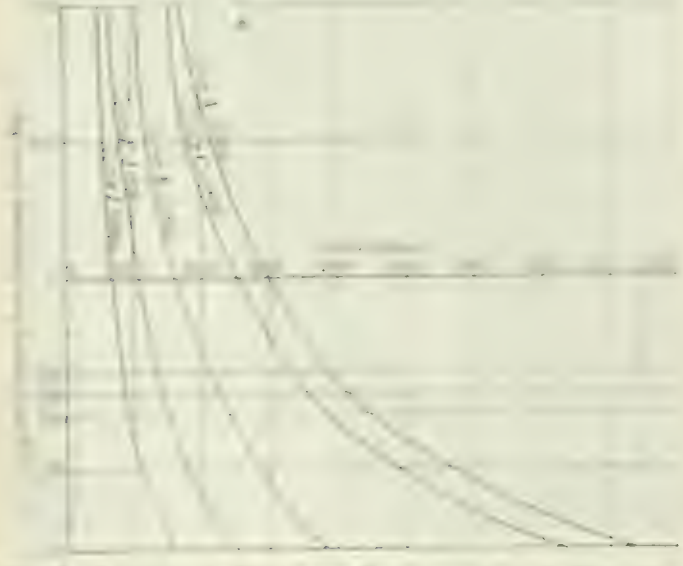
Test No. 1—Candlepower Distribution Distance to Left of Median Vertical Plane (Car Axis), Deg.	0	1	2	3	4	5	6	8
Degrees Above Horizontal								
1	1,680	1,600	1,160	710	600	560	480	250
½	2,200	1,900	1,210	....	700	....	....	280
Horizontal	2,900	2,500	1,600	1,140	960	760	630	310
Degrees Below Horizontal								
½	4,500	3,900	2,400	1,520	1,200	1,010	900	480
1	9,000	7,600	3,900	2,600	2,200	1,800	1,470	670
1½	18,000	16,200	9,300	5,800	4,100	3,500	2,700	1,130
2	46,000	36,000	21,000	10,700	9,200	7,400	6,000	2,500
2½	78,000	62,000	34,000	19,600	16,600	....	....	5,200
3	90,000	68,000	38,000	23,000	17,600	16,500	13,500	6,000
3½	62,000	47,000	25,000	....	12,800	....	....	4,300
4	29,000	20,000	11,900	8,200	7,000	5,200	4,500	1,880
5	4,100	.....	....	....	1,260	....	....	180

ight. The diagrams, of lenses at least, show that the simple convergent, or divergent, beam from a parabolic reflector, having a lamp filament either ahead of or behind the focal point, can be more effectively redistributed than can a compound beam, when the filament is centered at the focal point.

The illumination diagrams for device Nos. 1, 2 and 6 have been derived from tests made by the Electrical Testing Laboratories of New York City. These tests were made in accordance with the 1922 Illuminating Engineering Society specifications for State approval tests. The diagram for device No. 3 was derived from distribution curves published by the manufacturer of the device.

CANDLEPOWER DISTRIBUTION

Table 1 shows the report of a test of candlepower distribution in the combined beam from a pair of standard head-lamps mounted as on a car and equipped with the device under test. The figures in the table show the luminous intensity, expressed in candlepower, directed toward various points on a vertical screen located 100 ft. ahead of the test-lamps. The position of each of the test-points on the screen is defined by giving the angular distance of the point to the right or to the left of a vertical plane passing through the center-line of the car, and by giving the angular distance of the point above or below the level of the center of the head-lamps.



Curves for Various Angles of Tilt from the Head-Lamp Level

The first column shows the angle above or below the level of the center of the head-lamps and the other columns give the candlepower of the beam directed at various angles to the right and left of the median vertical plane between the test-lamps.

To lay-out the outline of areas of equal illumination with a fair degree of accuracy we should have information as to the illumination at the distances ahead of the car that are shown in the second column of Table 2. Assuming that the centers of the head-lamps are 3 ft. above the road level, the first column of Table 2 gives the angular distance below the head-lamp level of a line from the center of the head-lamp to the road level at the distance from the lamp given in the middle column of Table 2. By comparing the first columns of Tables 1 and 2, we find that we shall have to devise some means of securing data as to candlepower for the test-points 0.34, 0.42 and 0.70 deg. below the level of the head-lamps.

These candlepower values can be determined with sufficient accuracy by plotting curves for each of the angles in Table 1. Such curves are shown in Fig. 5. Distances along the X axis represent candlepower, and along the Y axis, the angular distance above or below the head-lamp level. If we draw a horizontal line at a distance below the X axis, corresponding to 0.34 deg., the distances from the Y axis to the intersections of this line with each of the curves will represent the candlepower directed toward the test-points 0.34 deg. below the level of the head-lamps. The same procedure for points 0.42 and 0.70 deg. below the level of the center of the head-lamps will give the candlepower for the remaining points needed to complete the calculation.

Before calculating the areas of illumination at road level it will be necessary to determine the illumination

TABLE 2—ANGULAR DISTANCES BELOW THE HEAD-LAMP LEVEL OF A LINE FROM THE CENTER OF THE HEAD-LAMP TO THE ROAD LEVEL AT DIFFERENT DISTANCES AHEAD OF THE CAR

Degrees Below Head Lamp Level	Distance Ahead of Test-Lamps, Ft.	Equivalent of 1 Deg., Ft.
0.34	500	8.75
0.42	400	7.00
0.50	340	6.00
0.70	250	4.30
1.00	172	3.00
1.50	114	2.00
2.00	86	1.50
2.50	68	1.20
3.00	57	1.00
3.50	50	0.88
4.00	44	0.77

TABLE 3—ILLUMINATION DISTRIBUTION AT ROAD LEVEL, FT-CANDLES

Distance Ahead of Test Lamps, Ft. / Distance to Left of Median Vertical Plane, Deg.	0	1	2	3	4	5	6	8
500	0.015	0.013	0.008	0.005	0.004	....	....	....
400	0.025	0.022	0.014	0.009	0.007	....	....	....
340	0.038	0.033	0.020	0.013	0.010	0.008	....	....
250	0.099	0.082	0.049	0.037	0.026	0.021	0.019	0.008
172	0.320	0.257	0.132	0.088	0.075	0.064	0.050	0.025
114	1.380	1.250	0.715	0.446	0.315	0.270	0.206	0.087
86	6.200	4.800	2.820	1.450	1.240	1.000	0.810	0.340
68	16.800	13.400	7.300	4.200	3.560	1.040	0.870	0.420
57	27.700	21.000	11.700	7.100	5.400	5.100	4.150	1.850
44	24.800	18.800	10.000	....	5.100	....	....	1.720

at the road level of the various points of the road at which lines projected from the head-lamps through the various test-points given in Table 1 will intersect the surface of the road. Table 3 gives the result of this determination. The illumination values for the various points are found by dividing the candlepower directed toward each point by the square of the distance of the point from the head-lamps.

The diagrams represent the area ahead of the car. Distances ahead are shown on a scale of 12.5 ft. to each square of the diagram; distances to the side, on a scale of 5 ft. to each square. To avoid complication four limits of illumination have been selected and each classification is represented by a distinctive tint on the diagram.

The area of lowest illumination contains all points at which the illumination is at least 0.1 and less than 0.4 ft-candles; the second, at least 0.4 and less than 1.6 ft-candles; the third, at least 1.6 and less than 4.0 ft-candles; and the fourth, 4.0 or more ft-candles. It will help us to realize what these values of illumination mean in the way of making objects visible if we remember that an illumination of 0.1 ft-candle is about three times the illumination given by a full moon on a clear night; under ordinary conditions it would permit us to discern objects at a distance of about 450 ft.

Areas of Equal Illumination

To determine the boundaries of the various areas of illumination we plot curves such as are shown in Fig. 6. Distances along the *Y* axis represent illumination, in foot-candles. Distances on the *X* axis represent the angular-distances of points from the center-line of the car on which the head-lamps are mounted. Taking the figures in Table 3, we plot curves showing the illumination of points at equal distances ahead of the car and at various distances to the side of the center-line of the car. For instance, curve *A*, Fig. 6, gives the foot-candles at 500 ft. ahead of the car and at 1, 2, 3, 4 deg. to the side of the center-line of the car. Curve *B* covers points 400 ft. ahead; *C*, points 340 ft. ahead; *D*, points 250 ft. ahead; *E*, points 172 ft. ahead; and *F*, points 114 ft. ahead. Curves for the other distances ahead of the car are not shown in Fig. 6.

To determine the boundary of the area having a minimum illumination of 0.1 ft-candle, we draw a horizontal line from the point on the *Y* axis corresponding to 0.1 ft-candle, and note the intersection of this line with the curves *A*, *B*, *C*, and so on. We find that the *A*, *B* and *C* curves are beyond the 0.1 ft-candle range and that the 0.1 ft-candle line intersects the *D* curve at 0 deg. to the side. In other words, the limit of the 0.1-ft-candle illumination will be 250 ft. directly ahead of the car. The 0.1-ft-candle line intersects curve *E* 2.6 deg. to the side, and at 172 ft. ahead of the car corresponds to a distance of 7.8 ft. to the side. The intersection with curve *F* is 7.8 deg. or 15.6 ft. to the side.

Completing the operation for the other curves gives a series of points that will outline the area of 0.1 ft-candle illumination, as shown on the diagram for device No. 1. The same procedure for 0.4, 1.6 and 4.0 ft-candles enables us to outline each of the four illumination areas. The diagram worked out by the method described above gives a graphic representation of the illumination at road level and shows to what extent the road will be lighted. A driving-light to be safe must not only show the surface of the road but must also make it easy for the driver of a car to distinguish objects above the road

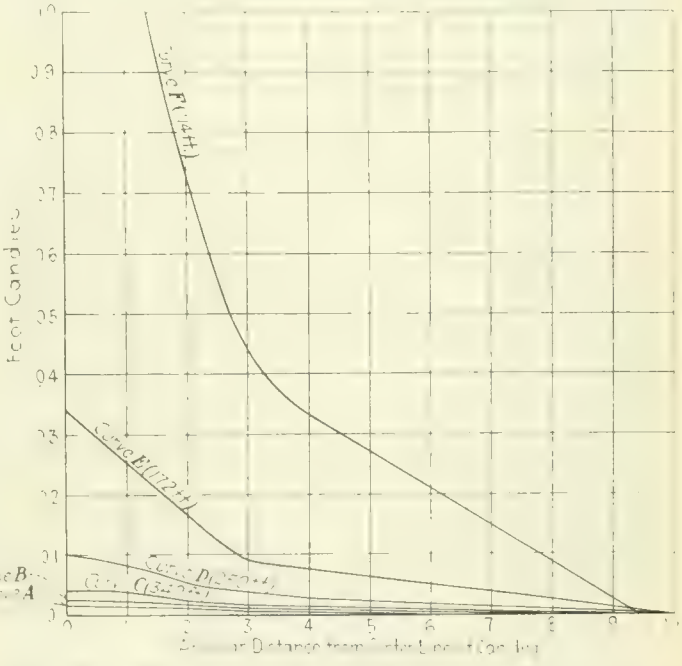


FIG. 6—CURVES SHOWING THE RELATION BETWEEN THE ILLUMINATION IN FOOT-CANDLES AND THE ANGULAR DISTANCE FROM THE CENTER-LINE OF THE CAR

level. By a similar process we are able to determine the beam cross-section at points 100, 200 and 300 ft. ahead of the car. This information together with the diagram of the illumination at the road level will give an excellent idea of the kind of driving-light a given device will produce. Although the diagrams show distinct areas of illumination it should be understood that the actual illumination on the road varies gradually from one area to the next. There will also be illumination beyond the limits of the 0.1-ft-candle area although it is not shown on the diagram.

A. H. WHITING

[illegible] this recording of the sudden and [illegible] of Sept. 9, 1923, of Allan Hart Whiting, aged 49 years, one of the founder members of the Society and prominent during its early history; and this regret is shared by all who have had the interests of the Society at heart ever since its inception.

In 1904 H. M. Swetland, publisher of *The Automobile*, supported the idea that a society should be formed to benefit all interests of the automotive industry, and tradition has it that discussions held in his office with leading engineers of the industry culminated in a decision to form a society of engineers who were engaged in the design and construction of automobiles. The three men present at this meeting were H. M. Swetland, A. H. Whiting and E. T. Birdsall. An informal organization was effected at that time by naming A. L. Riker as president, E. T. Birdsall as secretary and treasurer, and designating Messrs. Whiting, Birdsall and Swetland a committee to draft a constitution. This committee decided to name the organization the Society of Automobile Engineers, and presented a constitution that stipulated conditions of membership in the Society, specified the annual dues and provided for regular officers and a board of managers.

Under this constitution, in January, 1905, A. L. Riker was elected president; Henry Ford, first vice-president; John W[illegible], second vice-president; and E. T. Birdsall, secretary-treasurer. Six managers were elected also, namely, A. H. Whiting, L. T. Gibbs, H. M. Swetland, H. P. Maxim, H. W. Alden and H. Vanderbeek. Additional membership in the Society was acquired during 1905, and a formal meeting of the organization was held, Jan. 15, 1906, at the New Grand Hotel, New York City. The meeting comprised a dinner and a program at which engineering papers by Thomas J. Fay, Henry Hess and E. T. Birdsall were presented. At this time the officers and managers mentioned above were re-elected to serve during the following year. Mr. Whiting was present at this meeting.

Mr. Whiting was born at Spuyten Duyvil, N. Y., July 26, 1874. In 1896 he graduated with the degree of Bachelor of Philosophy from the electrical course of the Sheffield Scientific School of Yale University. From September, 1896, to July, 1899, he was connected with the Riker Electric Motor Co., and from that time until November, 1900, was assistant engineer and general superintendent for the Riker Motor Vehicle Co. His later business connections until May, 1905, included engineering, sales and managerial experience in responsible positions with the Electric Vehicle Co., Rainier Motor Corporation, Edison Storage Battery Co. and the Commercial Motor Co. Afterward he became president of the Whiting Motor Co., New York City. For many years this company was a dealer of the Mercer Motors Co., and recently of the Fox Motor Car Co.

Aside from his business, Mr. Whiting's chief interest was in the development of numerous motor-vehicle accessories in his private laboratory. He was a member of the Yale Club, the Engineers' Club and the Automobile Club of America. It is indeed deplorable that he should have become disheartened by a recent swift succession of business reverses that overbalanced his good judgment. He left a widow; there were no children.

STEPHEN M. LEE

Stephen M. Lee, assistant mechanical engineer in the Aeronautic Powerplant Section, U. S. Bureau of Standards, [illegible] of Washington, died at the age of 27 years, Sept. 21, 1923, from injuries caused by an explosion at the Bureau of Standard's laboratory. The disaster occurred during a test of a well known make of passenger-car engine in the altitude chamber, this being a part of the program of fuel research with which the Research Department of the Society is co-operating. Aviation gasoline of high volatility was being used as fuel, and low-temperature conditions obtained by refrigeration prevailed within the chamber while the engine was being run. A gaseous explosion inside the chamber burst its walls, partially wrecked the building and fatally injured Mr. Lee who, with others, was conducting the test.

Mr. Lee was born Nov. 14, 1895, at New London, Conn. His education in mechanical engineering was obtained at the Massachusetts Institute of Technology, Cambridge, Mass., and at Leland Stanford University, Cal., during the period 1913 to 1920. From July, 1917, to December, 1918, his practical experience was with the United States Naval Reserve Force. He became a commissioned ensign, the rating of first mate on submarine chaser No. 331, and operated its three 220-hp. engines. His subsequent experience prior to 1921 was in operating 10,000 kw. turbines, and in assembling and testing Diesel engines.

Feb. 18, 1921, he became an assistant in the laboratory for aeronautical research at the Bureau of Standards. He gave marked evidence of ability in research work and was promoted to the position of assistant mechanical engineer. His 1923 Annual Meeting paper entitled Testing Fuels for High-Compression Engines, in collaboration with S. W. Sparrow, also associated with the Bureau, and his own later paper for the 1923 Semi-Annual Meeting on Economic Motor-Fuel Volatility, are noteworthy examples of his contributions and indicative of the important work in which he was engaged, for the Bureau, relative to the field of fuel research. He had been assigned by the Bureau to direct the fuel-research work there. His engaging personality, his ability and promise of future achievement, make it most unfortunate that he was not spared to continue his work.

He was elected to Junior Member grade in the Society May 27, 1921.

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

PROPER DIMENSIONING IMPORTANT

Use of Both Bilateral and Unilateral Systems of Expressing Tolerances Proposed

Appreciating the importance of the proper dimensioning and expressing of tolerances in connection with dimensional standards, the Council appointed a special committee early this year to establish some uniform practice. The members appointed to this committee were Earle Buckingham, of Pratt & Whitney Co., G. C. Case, of the Lamson & Sessions Co., and E. H. Ehrman, of the Standard Screw Co., Mr. Buckingham being designated as chairman. Although the committee has not submitted a final report, Mr. Buckingham has submitted a comprehensive review of the situation, together with definite recommendations. It is appreciated that the subject is too far-reaching to expect a satisfactory decision to be reached by a small committee without the general advice of the industry. Mr. Buckingham's article is published herewith to elicit criticism and general information which will be of value to the industry in arriving at acceptable discussions on the problems involved.

Tolerances

The subject of tolerances is now being widely discussed, not only here but also abroad, particularly with reference to their application to various standards which are in course of preparation. It has been suggested that some uniform practice in regard to tolerances should be adopted. At the present time, the S. A. E. Standards follow no uniform rule, examples of almost every method existing in them. Before making any definite recommendations, it would be well to consider the various practices to determine if any one method is superior to the others; or, if not, to determine what conditions require different practices.

Tolerances may be divided into two general classes: Unilateral and bilateral. A unilateral tolerance is one wherein the permissible variation is in one direction only from a given nominal size; such as "one inch, plus nothing, minus five thousandths," or "one inch, plus five thousandths, minus nothing."

A bilateral tolerance is one in which the permissible variation is in both directions from a given nominal size; such as "one inch, plus or minus three thousandths."

Another question is often discussed and sometimes confused with the foregoing classification of tolerances, although it is entirely independent of them. This is the question as to whether the shaft or the hole should be standard. For example, if a minimum clearance of five thousandths is required between a one-inch shaft and hole at one time, and a minimum clearance of ten thousandths is required between another hole and shaft of the same nominal diameter, which member should be made of constant size and which should be varied to provide for the differing conditions?

Thus, in order to arrive at a standard practice that will be complete we must decide the following questions:

(1) Shall we use unilateral or bilateral tolerances?

(2) Shall the shaft or hole be basic?

In the second question, the term "shaft" represents all male surfaces, and the term "hole" represents all female surfaces.

One of the first instances in which definite tolerances were established was that of weights and measures used in commerce. In this Country the practice was to specify given tolerances, plus and minus (bilateral), from the fundamental standard. The amount of the tolerances varied according to the use or classification of the standard. The reason for this was to keep the average of the weights and measures used throughout this Country as close as possible to the fundamental units. This practice is shifting, however, as it created a tendency to work as closely as possible to the smallest limit, particularly in the case of standard package goods. For scientific purposes, a bilateral tolerance on weights and measures as small as possible is desirable; while for commercial standards of weights and measures, where the greatest good to the greatest number is desired, a plus tolerance only (unilateral) is gaining favor. While most of the factors governing the practice of tolerances as applied to standards of weights and measures are foreign to those governing mechanical standards, it is of some assistance to review them.

In discussing the subject of tolerances as applied to mechanical standards, we must differentiate between mating and non-mating surfaces. For the first class of surfaces, we must always consider the relationship between the two mating surfaces. For the second class, where ample clearances are always present one surface only need be considered.

Non-mating surfaces or atmospheric fits

For non-mating surfaces, and other unimportant dimensions where tolerances are specified, the class of tolerances that should be used depends entirely upon the requirements of the manufacturing processes employed. For example, the diameter of the head of a rivet, the diameter or thickness of a washer, dimensions of forgings, castings, hot-rolled material, etc., should be permitted to vary in the direction that variations develop in normal manufacture. Thus, if a certain size is controlled by the size of a tool alone, and this tool grows larger with use, the logical thing would be to make the nominal size the minimum limit, and permit a plus tolerance only (unilateral). On the other hand, if, in addition to the wear on the tool, an adjustment of the machine were also involved, so that the normal variation of the dimension in question was either larger or smaller, a plus and minus (bilateral) tolerance should be given. In other words, the type of tolerance used should follow the nature of the variations which exist in the production of the respective material in question.

Mating surfaces

The problem of tolerances on mating surfaces is entirely different from that of non-fitting ones, or atmospheric fits. We are now considering interchangeable parts. We establish tolerances to assure that under the tightest possible conditions the fit between mating parts will not be too tight; while under the loosest possible conditions they will not be too loose. The first step toward the establishment of tolerances should be to determine the tightest and loosest conditions we are willing to accept. The difference between these conditions represents the sum of the tolerance on the mating parts.

After this value is decided upon the next step is to apportion it between the two mating parts. The way in which this sum is divided should be governed largely by the ease or

or unilateral, depending entirely upon the nature of the variations which develop in manufacture. There can be no question here of maximum-hole basic or maximum-shaft basic, as there is but one member to consider.

No mention has been made in the foregoing of the location of holes. Where tolerances are required on such dimensions, usually they should be bilateral, as a variation in either direction is generally equally dangerous. The variation in the distance between shafts carrying mating gears, however, should always be unilateral and plus; otherwise the gears might be too tight to assemble, while a slight increase in the backlash between gears is seldom of such importance. In other words, the tolerance on the distance between holes should be bilateral when variation in either direction is dangerous and should be unilateral when a variation in one direction is less dangerous than a variation in the other direction.

On mating surfaces, with but few exceptions, the tolerances should be unilateral.

The minimum hole should be of basic size in all cases where the simplification and use of standard tools represents the greatest economy.

The maximum shaft should be of basic size in all cases where the use of standard purchased material without further machining, and the provision of special tools for machining the mating part, represent the greatest economy.

One exception to the use of unilateral tolerances on mating surfaces occurs where tapers are involved. In this case either bilateral or unilateral tolerances may prove advisable, depending upon conditions. These should be determined in the same way as the tolerances on distances between holes. When a variation either in or out of the position of the mating taper surfaces is equally dangerous, the tolerances should be bilateral. When a variation in one direction is of less danger than a variation in the other direction, the tolerances should be unilateral and in the less dangerous direction.

Methods of Expressing Tolerances

Many different methods are employed to express the tolerances on drawings or specifications. The essential consideration in the choice of such a method is to choose the one which offers the least opportunity of being misunderstood. The only purpose of a drawing is to record or convey the necessary information to enable a given piece to be manufactured. The method used to convey this information depends largely upon how it is to be used. Some parts, made in extremely large quantities, are controlled in manufacture entirely by the tools and gages. Sometimes drawings are not used at all in the production departments. In such cases the part drawings can specify limiting dimensions only.

In other cases, where parts are made in smaller quantities, the drawings themselves are the only special facilities employed. In these instances the information should be given in such a manner that the parts can be roughed-out and finished with the least chance of misunderstanding. As an example, we will assume that we have a shaft and hole, nominally 2¼ in. in diameter, and that the minimum clearance is 0.001 in., while the maximum clearance is 0.005 in. Several ways of expressing this information are as follows:

Diameter of hole, 2.250
2.252
Diameter of shaft 2.249
2.247

The foregoing gives the limiting sizes.

Diameter of hole, $2.250 \begin{smallmatrix} +0.002 \\ -0.000 \end{smallmatrix}$
Diameter of shaft $2.249 \begin{smallmatrix} +0.000 \\ -0.002 \end{smallmatrix}$

The foregoing gives one limiting size on each part with a tolerance.

Diameter of hole, $2\frac{1}{4}'' \begin{smallmatrix} +0.002 \\ -0.000 \end{smallmatrix}$
Diameter of shaft $2\frac{1}{4}'' \begin{smallmatrix} -0.001 \\ -0.003 \end{smallmatrix}$

The foregoing method is widely used when parts are made in small quantities and where no gages are used in the

TABLE 1—STANDARDS WITH BILATERAL TOLERANCES

Name of Standard	*S. A. E. Handbook Page*	*Nature of Surface*
Insulated Cable	B33	Atmospheric Fit
Insulated Cable	B36	Atmospheric Fit
Storage Battery Jars	B40	Atmospheric Fit
Plain Washers	C5c	Non-Mating (Thickness)
*Rod-Ends	C9	Mating (Diam. of hole)
Rubber Hose for Gasoline	C51	Non-Mating
Ball Studs	C58b	Taper Diameter
Round High-Strength Steel Wire	C71	Atmospheric Fit
Motorcycle Wheels	F3	(Circumference of Rim)
Motorcycle CC Rims	G9	Fits Rubber Tire
Solid-Tire Base-Bands	G11	Atmospheric Fit
Solid-Tire Felloe-Bands	G12, 13	Atmospheric Fits
Solid-Tire Demountable Rims	G15	Non-Mating
*Spring-Eye Bushings	H5	Mating (Diam. of Eye)
Width of Spring Ends	H6	Non-Mating
Door Locks and Handles	K45	Non-Mating

roughing operations. In many such cases the measuring tools used in the roughing operations are steel scales and calipers only. The use of decimals for the nominal size would be confusing to the operator who is roughing-out material. As he leaves from 1/32 to 1/16 in. for finishing, the few thousandths of an inch specified for the allowance and tolerance is of no importance to him. The operater who finishes the surfaces usually measures them with micrometers, and in measuring the shaft it is as easy, or easier, for him to measure from one to three thousandths under 2¼ in. as it would be to measure from 2.249 to 2.247 in.

Any of the stated methods are entirely suitable for expressing unilateral tolerances. All of them are self-evident.

Another method, which should be discouraged, is sometimes used to express tolerances. This method expresses an intrinsically unilateral tolerance as regards the nominal size as a bilateral tolerance on the mean size. It is as folows:

Diameter of hole, 2.251 ± 0.001

Diameter of hole, $2.151 + 0.002 - 0.001$

There is no value in such cases in emphasizing the mean size. It is more liable to confuse than to simplify. Furthermore, the original tolerances specified often are changed as time and experience indicate. In the foregoing example, if the tolerances on both surfaces were increased a thousandth, we would then have the following:

Diameter of hole, $2.251 + 0.002 - 0.001$

Diameter of shaft, $2.248 + 0.001 - 0.002$

In such cases—and many of them exist—the denoted size is no longer the mean size, and has absolutely no excuse for existence. It is best practice, in all cases where the tolerances are unilateral ones from a standard nominal size, to express them by one of the first three methods shown.

In the case of a bilateral tolerance on a non-fitting surface or atmospheric fit, the tolerance is best expressed as a bilateral one, as follows:

$\frac{3}{4} \pm 1/32$

Sometimes it is desirable to express the dimensions in decimals, as follows:

0.250 ± 0.005

In addition to the methods of expressing tolerances, there is the subject of the proper methods of dimensioning drawings with tolerances so that there can be no misunderstanding. This is such a large subject in itself that no other mention, except calling its existence to attention, will be made now.

SUMMARY

It should be evident from what is said above that there is proper use of both unilateral and bilateral tolerances; of making the minimum hole basic and also of making the maximum shaft basic. Also that varying methods of expressing these tolerances and allowances can be employed to advantage. The attempt has been made to indicate in general their proper application.

S. A. E. Practice in Standards

It is of interest in this connection to review some of the existing S. A. E. Standards, in which tolerances are specified, to see how nearly they already agree with the practice proposed in this discussion. Possibly some of the standards have been overlooked in making this summary, but practically all of them have been included.

There are 46 standards wherein unilateral tolerances only are used. There are 17 standards in which bilateral tolerances only are used.

There are 27 standards in the case of which both unilateral and bilateral tolerances are used, sometimes on different surfaces of the same standard part and sometimes on the same surfaces of different sizes in the series.

The best practice is to use unilateral tolerances only on mating surfaces, while either unilateral or bilateral tolerances can be used on non-mating surfaces. We will therefore review in detail only the bilateral tolerances.

TABLE 2—STANDARDS WITH UNILATERAL AND BILATERAL TOLERANCES

Name of Standard	*S. A. E. Handbook Page*	*Nature of Surface Where Bilateral Tolerance Is Used*
Lamp Glasses	B6	Non-Mating (The Three smaller sizes use unilateral tolerances only)
*Magneto Mountings	B14a	Mating (Shafts and Coupling Bore)
Generator Mountings (Flange Type)	B15a	Non-Mating
Annular Ball-Bearings (Open)	C32	Non-Mating (Width. Note, on several other types the tolerance is unilateral on this surface also)
Annular Ball-Bearings	C33a	Non-Mating (Width)
Annular Ball-Bearings	B33b	Non-Mating (Width)
Annular Ball-Bearings	C33c	Non-Mating (Width)
Thrust Ball-Bearings	C40	Non-Mating (Thickness)
Thrust Ball-Bearings	C41	Non-Mating (Thickness)
Thrust Ball-Bearings	C42	Non-Mating (Thickness)
*Roller Bearings	C43	Mating (Bore) Non-Mating (Width)
*Roller Bearings	C44	Mating (Bore) Non-Mating (Width)
Fuel and Lubrication Pipe Fittings	C47	Non-Mating
Ball Studs	C58c	Taper Diameter
Plain Hex-Head Bolts and Nuts	C60, 61	Non-Mating
Ball Hex-Head Bolts and Nuts	C62, 63	Non-Mating
Tachometer Drive	C75	Mating (Square Broached Hole Non-Mating
Tachometer Drive	C76	Non-Mating or Clearance
Tachometer Drive	C77	Clearance
Turnbuckles	C79	Atmospheric Fit
Turnbuckles	C81	Mating (Thickness of Eye) Atmospheric Fits
Roller-Chain Sprockets	E4	Clearance
Three-Joint Propeller-Shafts	E6b	Diam. of Taper
Clutch Facings	E19	Location of Holes Non-Mating (Thickness)
Motorcycle Spokes	F4	Atmospheric Fits
Pneumatic-Tire Rim-Sections	G3	Non-Mating (Fits Tire)
Felloe-Bands	G7	Non-Mating

Of the 11 standards in Table I only two have bilateral tolerances on mating surfaces. These items are starred in the tabulation, namely, Ball Bars and Spring-Eye Bushings. It would seem desirable to have these corrected at the earliest opportunity.

The standards in Table 2 use bilateral tolerances and also unilateral tolerances. The tabulation indicates the nature of the surface on which the bilateral tolerances only are used. Of the foregoing 27 standards, only 5 have bilateral tolerances on mating surfaces. These items are starred in the tabulation. Thus, out of 44 standards where bilateral tolerances are used, only 7 need be changed in order to bring them all in agreement with the practice recommended.

There are 21 standards where the minimum hole is basic.

There are 14 standards where the maximum shaft is basic.

There are 9 standards where both mating parts start at basic size.

There are several standards in which neither member is at basic size. Most of these are of special form. In a few cases, where both tight and loose fits are specified, neither member is of constant size, so that tools and gages are needed not only for each size but also for each class of fit. This is an extremely uneconomical practice and should be corrected.

This discussion and brief summary of S. A. E. Standards is submitted for comment and criticism. It seems very important to bring this matter before the Society at this time in order to work out some uniform practice to which all of the Society Standards may adhere.

Whatever practice is adopted, it should be definite enough to avoid confusion, and also be flexible enough to meet the many varying conditions with which the industry as a whole must contend.

SIMPLE BRAKE TEST NEEDED

Activity of Police in Inspecting Brakes Warrants Adoption of Standard Brake Test

Further recommendations to decrease automobile accidents were made in the first report of a special committee appointed by the Grand Jurors' Association of New York City to study the causes of the steady increase in deaths due to motor cars. The suggestions were the outcome of a conference with officials concerned with the automobile trade, traffic and the enforcement of the rules, regulations and ordinances covering automobile operation. The fifth recommendation proposed a strict examination for defective brakes.

The test used by the New York police safety-squad engaged in testing automobile brakes is as follows:

> The officer takes a seat by the driver and directs that he speed up the car to between 15 and 18 m.p.h. Then at his direction the driver applies the foot-brake. If the car is stopped within 30 ft. the foot-brake is considered satisfactory and the driver is instructed to repeat the performance, but using his emergency brake. If either brake is found defective the driver is ordered to return within three or four days for a retest. If both brakes are found defective the driver receives a summons to appear in court.

The tests are generally conducted on the city streets, irrespective of the condition of the pavement with the exception that wet streets are avoided.

The Police Department does not look with favor upon the testing of brakes by machines designed for that purpose. They feel the only satisfactory test is a service test made under normal conditions. The owners of certain New York police patrols all of effective in actual day design are of [illegible] They feel that car manufacturers have paid no attention to brake design for the last 10 years. They consider brakes to be the most important unit in the car, owing to their importance as a means of avoiding fatalities in traffic. They feel that, with the increasing practice of passing cars by driving together with the ever present danger of wet streets due to rain, brakes should be designed which will meet such conditions.

This subject is receiving the careful consideration of the Subdivision on Brake Tests, of which Clarence Carson of Dodge Brothers is chairman. Comments received from committee members in reference to the New York practice of testing brakes indicate that the requirements are considered fair, but that a definite standard should be promulgated which might be followed generally throughout the Country. The following comments received are of special interest.

Stopping Distances

In general we believe that any brake tests should consist of an actual driving test, preferably on a dry road surface such as concrete where the friction between the wheels and the road is fairly constant. Cars should be tested with full passenger-loads if possible. We expect our touring cars to stop under the above conditions in the following distances:

Car Speed, M.P.H.	Stopping Distance, Ft.
10	6
15	12
20	28
25	38
30	65
35	80
40	120

We would consider the above distances as shown to be rather more exacting than could be expected from the ordinary rear-wheel brake equipment, but are giving them so they may be considered as the best that can be done without using front-wheel brakes and one that is commercially practical with a well-designed transmission type of service-brake.

Test Conditions

The stipulation of bringing a car to rest within 50 ft. at 20 m.p.h. seems very reasonable indeed. We know that properly designed rear brakes can always be relied on to do better than this on any reasonable surface.

The present allowance for a variation in speed between 15 and 18 m.p.h., implying a variation of 20 per cent in speed and 44 per cent in stopping distance, is entirely too inaccurate. Accurate means should be available for checking the speed of the car.

The testing track should be under cover, as surface conditions, especially on tarred roads, vary considerably with the temperature as well as with moisture. The tire pressure should be stipulated and should be that recommended for use by the makers of the vehicle, rather than the high pressures called for by some of the tire manufacturers.

A standard loading should be provided, which might reasonably consist of the full complement of passengers for two and three-passenger machines, and four persons for larger passenger cars (150 lb. to be allowed for each passenger).

Nature of Test

In the test of brakes on cars we have not yet found any satisfactory mechanical means for doing the work and believe that a road test is the best method at the present time. This road test can be carried out by any person of average intelligence and requires no special technical knowledge on the part of those conducting the test.

Under average dry road conditions the stopping distances when running at the rate of 20 m.p.h. should be 37 ft. To allow for possible nervousness on the part of the car operators when undergoing this test, we have usually allowed 10 per cent over this distance, calling 40 ft. satisfactory for stopping the car when going at 20 m.p.h. In conducting these tests it is usually well to have some mechanic as an observer to note the adjustment of the bands on the wheels and

the distance the foot-pedal goes down toward the floorboard when applying the brakes.

We know that this test works well and it can be carried on very expeditiously by any police force.

Brake Surface Area

We are heartily in favor of brake tests, not only on account of the number of brakes found defective in tests we have observed, but also because of the number of drivers we have found who do not know how properly to bring their cars to a stop.

It seems to me that more attention is being paid to the brakes on the wheels in particular than to the entire braking system in general. The ratio of square inches of braking surface to 100 lb. of car weight varies through a great range and it seems to me that this is a matter which could be standardized. There is also a great variation of brake-drum diameters. I believe this matter is one which should receive some consideration and the brake-drum diameter, together with its width, should bear a certain relation to the car weight.

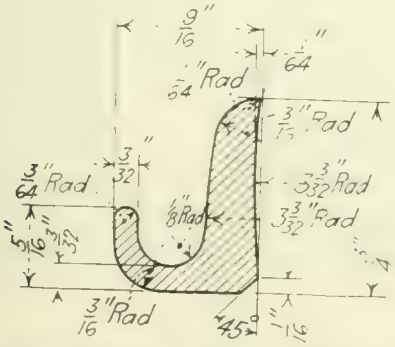
I feel that some study could be profitably given to the linkage system and the pressure required on the foot-pedal to produce the desired deceleration. The number of women drivers is increasing every day and a woman cannot exert the pressure on a foot-pedal that a strong man can. Consequently, I believe that the brake system should be so designed that the brakes can be effectively applied by the average woman driver.

REVISED MOLDING STANDARDS PROPOSED

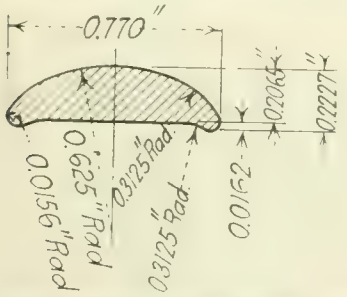
Original Recommendation Covering Aluminum Molding Changed as a Result of Comments

The progress report which was published in full in the May issue of The Journal has been revised as a result of criticism received from body builders and passenger-car manufacturers building bodies. It has been found that the demand for ell and tee molding is so limited that it is inadvisable to attempt to standardize any particular styles. On the other hand, the use of belt molding being so extensive, it was decided that more than one type should be included in the standard. The recommendation has therefore been revised to include one type of drip molding and three types of belt molding, there being three sizes for one of these types. The complete report thus covers six types and sizes of molding. The report is given in full in the accompanying illustrations and table.

It should be appreciated that the moldings proposed are standard at the present time, having been selected from those sizes most widely used in present practice. As the molding manufacturers are called upon to furnish an almost unlimited number of types and sizes of molding, practically no two orders of which specify the same cross-section, the advantage to the industry if the proposed types of molding are adopted as standard practice will be appreciated.



Estimated Weight per Linear Foot, 0.180 Lb.
Fig. 1—Drip Type of Molding



Estimated Weight per Linear Foot, 0.143 Lb.
Fig. 2—Type A Belt Molding

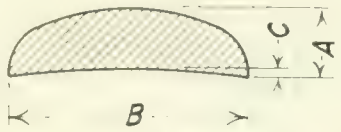
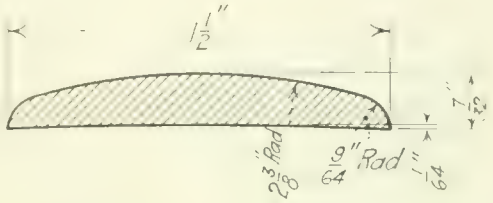


Fig. 3—Type B Belt Molding

No.	A	B	C	Estimated Weight Per Foot, Lb.
B1	1/4	7/8	0.025	0.186
B2	1/4	1	0.025	0.228
B3	1/4	1 1/4	0.025	0.286



Estimated Weight per Linear Foot: 0.331 Lb.
Fig. 4—Type C Belt Molding

PROPER SPARK-PLUG SPACE IMPORTANT

Minimum Clearance Dimension to Be Determined as a Guide for Future Engine Design

The Spark-Plug Subdivision of the Electrical Equipment Division has indicated that it would be desirable to establish a standard minimum dimension for the vertical distance from the spark-plug gasket-seat to the nearest interfering object. This dimension is considered important as there is a tendency on the part of some manufacturers to make this clearance such that certain types of spark-plug which the public demands cannot be used because of lack of proper clearance.

In order to determine whether it is feasible to standardize such a dimension, information has been obtained on present practice and turned over to the Spark-Plug Subdivision. It is expected that a definite recommendation based on this information will be submitted at an early date.

IRON AND STEEL DIVISION ACTIVE

Physical-Property Charts to Be Extended to Include Chromium and Chromium-Vanadium Steels

The charts of physical properties given in the S. A. E. Handbook are considered as indicators of what may be expected of the average product of a given range in analysis when tested in 1-in. sections, from which tests are taken from standard location. Quoting from page 208 of the S. A. E. Handbook:

> In the table it was seemed advisable to use only average minimum figures for tensile-strength, yield-point, reduction of area and elongation, based on the following considerations, heat-treatment being assumed:
>
> (1) The lowest yield-points and tensile-strengths are produced with steels at the bottom of a given range in carbon
>
> (2) The lowest reductions in area and elongations are produced with steels at the top of a given range in carbon
>
> Thus for Steel 1035, the average minimum yield-points and tensile-strengths are given as of a steel containing 0.30 per cent carbon; average minimum reductions of area and elongations as of a steel containing 0.40 per cent carbon

The results given in the present charts were estimated from accumulated data, in most cases on sizes under 1½ in. round.

The Subcommittee on Chromium and Chromium-Vanadium Steels feels that data of this kind for these types of steels will not give entirely satisfactory information on material covering a 10-point carbon-range in any of the alloy steels and will be of no practical value for the chromium steels covered by the committee.

In the S. A. E. charts, while the lowest tensile-strength and elastic-limit apply on steels at the bottom of a given carbon-range, and the elongation and reduction on steel at the upper limit in the carbon-range, no consideration whatsoever is given to the alloying elements. The minimum average values, to be of practical use, should take this point into consideration. Whether the alloying elements are on the high or low side of the range has tremendous influence on the physical properties developed. For instance, on S. A. E. Steel 3140 a tensile reduction in results would be obtained on a 1½-in. round from two analyses as follows: Carbon, 0.40; Chromium, 0.45; Nickel, 1.00 (lower extremity of the range in alloys) and Carbon, 0.25; Chromium, 0.75; Nickel, 1.60 (upper extremity of the range in alloys). The first-mentioned analysis will not by any means meet the results in tensile strength as indicated on the graphs of average physical properties of a 1½-in. round with an 800-deg. fahr. draw. Likewise, on S. A. E. Steel 3120 and various other types, results are much too high to be representative of average conditions with the limits on the lower extremity of the range.

For chromium and chromium-vanadium steels, the difficulties in giving graphs of practical value in accordance with the present method employed are greatly increased. The reason for this lies in the very nature of the alloying elements or elements, where the increase in physical properties imparted from these elements is due directly to the formation of complex carbides, of which these alloying elements are components.

The recommendation of the Subcommittee on Chromium and Chromium-Vanadium Steels is as follows:

> That results be given showing actual results obtained on a definite size (1½ in. round has been decided upon as representative of requirements) of definite chemical properties as indicated. Definite range under consideration and with graphs developed from actual tests on each material.

The recommendation of the Subcommittee has been submitted to the members of the Iron and Steel Division and metallurgists connected with the different automobile companies for comment in order that the Committee may be confident that when the data are compiled they will be of the most value to the users thereof.

BRAKE-DRUM STANDARD SUBMITTED

Future Requirements Met by Eight Drum-Diameters, But Only Maximum Width Specified

The Subdivision on Brake-Drums has submitted to the Axle and Wheels Division a final report covering the standardization of brake-drums. The recommendation, which is given in the accompanying table, will be acted upon at the next meeting of the division and, if approved, submitted to the Standards Committee for action at the Annual Meeting

BRAKE-DRUM DIMENSIONS PROPOSED AS STANDARD

No.	Outside Diameter	Inside Diameter	Stock Thickness	Maximum Height of Wall	Maximum Eccentricity
0 (Ford)	8 1/8	8.005–7.995	0.1250	1 5/16	0.020
1	10	9.790–9.770	0.1250	1 5/8	0.020
2	11	10.710–10.690	0.1650	2 1/2	0.020
3	12	11.666–11.646	0.1875	2 1/2	0.020
4	13	12.666–12.646	0.1875	2 1/2	0.020
5	14	13.635–13.615	0.2030	2 3/4	0.020
6	15	14.635–14.615	0.2030	3	0.020
7	16	15.605–15.585	0.2180	3 1/2	0.030
8	17	16.541–16.521	0.2500	3 1/2	0.030

Although the Subdivision voted favorably on the report some comments were submitted which will be considered by the division when final action is taken, the principal criticism being that maximum brake-drum widths, rather than definite widths, have been specified. It is apparently felt that the standard would be of more value if a definite width or series of widths were specified for each brake-drum diameter. Comments in reference to this point would be appreciated by the division members.

LEATHER GRADE NAMES CONFUSING

Upholstery Leather Specifications Being Prepared to Obtain Uniformity

At the present time trade practice as regards the nomenclature of the various splits of hides varies to such an extent that it is almost impossible to determine what split is designated by a grade name. There is also a total lack of uniformity in the leather specifications used by the various companies. Appreciating that the formulation of definite specifications would be of extreme value to the body industry, the Passenger-Car Body Division appointed a Subdivision some time ago to recommend definite specifications for upholstery leather. K. L. Herrmann, of the Studebaker Corporation, was appointed chairman, the other members being F. E. Watts, Hupp Motor Car Corporation; W. H. Graves, Packard Motor Car Co.; W. N. Davis, Cadillac Motor Car Co.; and R. K. Mitchell, Maxwell Motor Co., Inc.

Subsequent to the appointment of this Subdivision, R. C

Bowker, of the Bureau of Standards, was appointed to the Subdivision in view of the Bureau's work in developing specifications for upholstery leather for Government use.

Information was obtained from the various leather users as to the specifications they were purchasing to, but it was found that considerable study would have to be given to the subject. It was, for instance, found that many companies would not accept hides patched with leather of the same grade or thickness and skived so as to be unnoticeable from the finished side. Study of this problem indicated that the use of certain glues would make this practice satisfactory to leather users. As the result of close cooperation between the Subdivision and the Bureau of Standards, information has been obtained by the Bureau which is of considerable interest in the connection. This information has been issued as Letter Circular LC 97 of the Bureau of Standards and is given hereinafter in full with the exception of illustrations showing the detailed results for full-grain and machine-buffed splits.

Notes on Upholstery Leather

In connection with the development of specifications for the different grades of upholstery leather for Government use and as a result of a request for cooperation on the same subject from the Passenger-Car Body Division of the Society of Automotive Engineers, certain investigations have been made relative to standards which will serve as a measure of the quality of these leathers. The procedure followed

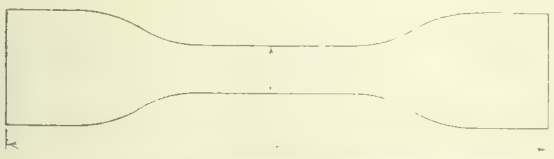


Fig. 6—Type of Tensile Test-Specimen Used

and the results obtained in this investigation are presented as a basis for the selection of satisfactory specification requirements, and also to stimulate further interest and work on a subject regarding which few data are available.

Definitions of Grades.—Since some confusion has existed regarding the meaning of the commercial classifications of grades, the following is suggested as a possible standard which covers the three grades mostly used by automobile manufacturers:

Grade	*Definition*
Full-Grain (Snuffed)	The first split from a hide containing the full grain of the leather, the surface of which is shaved either by hand or machine, removing shavings of no appreciable size or thickness.
Machine-Buffed	The first split from a hide after a thin layer of the grain thickness (called a buffing and approximately 1/64 in. thick) has been removed.
No. 1 Split	The second split or thickness of a hide secured after either a full-grain or machine-buffed split has been removed. (The No. 1 Splits under both a full-grain or a hand-buffed split appear to be near enough equal in quality to have the same classification although in the latter the cut is begun approximately 1/64 in. deeper.)

Selections.—One of the chief causes of trouble in the use of leather for upholstering is the number of defects in the hides. There has been little attempt to make a standard selection to which all tanners will adhere. Most of these defects are caused by circumstances entirely outside of the tanner's control and it would naturally be more to his interest to sell his leather on the basis of "tannery run." In the case of the consumer, where production is important and hides are cut on a piece-work basis, it appears essential that the selection of leather being used at any one time be as uniform as possible. The following specifications as to selections have been suggested:

A—Selection shall consist of leather free from brands, patches, knife-cuts, knife-scores and open grub-holes, excepting that 10 per cent of the hides may contain not over 4 open grub-holes

B—Selection shall consist of leather free from brands, knife-cuts and knife-scores. Hides may contain not over 4 patches 1½ in. in the longest dimension and not over 9 open grub-holes

No attempt has been made to cover the various other selections which may contain various types of brands and other imperfections. It is believed that a large portion of the leather required can be furnished under the above and that, where a consumer finds he can use lots with certain types of brands or more of the defects than allowed in the above, negotiations can be made with the contractor regarding a definition of the selection he will purchase.

Shapes and Sizes of Hides.—An important factor is the shape of the hides since they will generally cut to better advantage the nearer they are to being square in shape. The shape is governed chiefly by the type of animal from which the hide comes and to a less degree on the manner of skinning. Where hides of nearly uniform width are required the width across the brisket must be specified. With reference to area the idea at one time seemed to be to get as spready hides as possible. However, the Leather Subdivision of the Passenger-Car Body Division of the Society of Automotive Engineers has already demonstrated that smaller hides can often be cut to advantage and in fact to such an extent that the tanners will have no cause for the complaint that hides of large area are always demanded. Specifications for maximum, minimum and average area in square feet must be specified by the purchaser according to the use of the material.

Thickness.—The common practice among tanners is to gage the thickness by ounces. Since it is stated that an ounce is equal to 1/64 in., the following is suggested as a thickness specification that can be readily understood by all:

> The leather shall be 3/64 in. in thickness plus or minus one half of 1/64. The thickness shall be measured with a Woburn gage or equivalent

Cracking of Coating.—The cracking of the coating is an important factor in the use of upholstery leather and it is suggested that the coating should show no evidence of cracking when the leather is doubled on itself by hand, coating side out, at 32 deg. fahr.

Fiber Appearance.—With reference to fiber appearance, a vertical section of full-grain leather shall show approximately 50 per cent of the thickness to be made up of the fine

Fig. 7—Type of Tear Test-Specimen Used

fibers and a vertical section of machine-buffed leather shall show approximately 25 per cent of the grain fibers.

Physical Test Data.—In order to determine the magnitude of the physical properties of upholstery leather 10 hides were submitted by automobile manufacturers for test. The hides submitted are listed below according to grade and code number.

Grade	*Code Number*
Full-Grain	A, B, C, H and I
Machine-Buffed	D, F and J
No. 1 Split	E and G

One-half of each hide was divided into blocks approximately 6 by 12 in. From each block three samples were cut

with a die for tensile tests. The percentage of stretch at failure in a gage length of 2 in. was noted on the same samples. The average of the three values was used as representing the value for the block. Three test specimens were also cut from each block. One test specimen from each block was used for the grab test and the stretch at failure was also noted for this sample.

The grab test sample was 3 by 6 in. and was placed length-

AVERAGE PHYSICAL PROPERTIES DETERMINED FROM TEST-SPECIMENS CUT LENGTHWISE OF THE HIDES

Hide	Breaking Strength, Lb	Tensile Strength, Lb. per Sq. In.	Percentage Elongation at Breaking Point Gage Length = 2 In.	Tensile Strength per Grab Test, Lb.	Percentage Elongation at Failure in Grab Test	Tearing Strength Lb	Average Thickness In
A	48	2350	41 0	189	42	7 3	0 041
B	52	2060	39 7	195	41	9 4	0 050
C	56	2860	38 0	225	41	8 0	0 039
H	52	2475	38 0	168	41	7 8	0 041
E	40	2235	42 1	156	36	7 2	0 038
D	58	2925	39 6	208	46	14 8	0 043
F	60	2955	47 1	229	51	15 1	0 041
J	43	2140	34 7	194	36	12 1	0 042
E	46	2470	36 1	253	39	16 6	0 041
G	68	3045	37 4	309	39	21 2	0 047

AVERAGE PHYSICAL PROPERTIES DETERMINED FROM TEST-SPECIMENS CUT CROSSWISE OF THE HIDES

Hide	Breaking Strength, Lb	Tensile Strength, Lb. per Sq. In.	Percentage Elongation at Breaking Point Gage Length = 2 In.	Tensile Strength per Grab Test, Lb.	Percentage Elongation at Failure in Grab Test	Tearing Strength Lb	Average Thickness In
A	45	2170	43 0	163	40	7 0	0 042
B	51	2010	39 0	201	41	8 3	0 051
C	56	2765	38 0	212	40	7 2	0 039
H	51	2460	37 0	186	36	6 7	0 045
E	41	2265	39 2	160	38	7 4	0 036
D	56	2815	38 0	225	42	14 6	0 043
F	62	2715	53 0	228	53	16 5	0 040
J	41	1960	34 7	190	37	13 3	0 042
E	41	1985	39 0	204	41	19 1	0 041
G	68	2740	36 0	292	39	21 5	0 046

wise in the testing machine, the clamps being 3 in. apart. The upper jaw of each clamp was 1 in. in width and the lower jaw 4 in. The test-specimens for tensile strength and tests are shown in the accompanying illustrations.

Beginning with block No. 1 at the tail, the test-specimens were cut in a lengthwise direction. Samples from alternate blocks were cut in the same direction, while those from the remaining blocks were cut in the crosswise direction. The data obtained give results of the variation in physical properties for different locations on the hide in both the lengthwise and the crosswise directions and for three grades of leather. The average values for each hide are given in the accompanying tables.

A simple test suggested for determining the strength of the various leathers is to punch a hole and insert the hook of an ordinary spring-balance suspended in a suitable place. The sample is pulled and the pounds pull noted when tearing starts at the punched hole. A number of tests are made using this method.

Summary.—The results show that the greatest variation between the different grades is not in tensile strength, but in a test which involves tearing, the grab test or the test with the spring-balance. For laboratory examination it is

AVERAGE PHYSICAL PROPERTIES DETERMINED FROM TEST-SPECIMENS CUT LENGTHWISE AND CROSSWISE OF THE HIDES

Hide	Breaking Strength, Lb	Tensile Strength, Lb. per Sq. In.	Percentage Elongation at Breaking Point Gage Length = 2 In.	Tensile Strength per Grab Test, Lb.	Percentage Elongation at Failure in Grab Test	Tearing Strength, Lb.	Average Thickness In
A	47	2260	38 5	186	40	7 1	
B	51	2060	39 3	198	41	8 8	
C	56	2830	38 0	217	41	7 6	
H	52	2475	37 5	177	39	7 2	
E	40	2235	40 5	158	36	7 6	
D	57	2925	38 8	231	44	14 7	
F	57	2855	50 0	227	52	15 8	
J	43	2020	34 7	192	38	12 7	
E	46	2225	37 5	219	40	17 8	
G	63	2690	36 7	300	39	21 4	

considered that the grab test is most satisfactory with the following limitations on the results for the different grades regardless of the location on the hide.

Grade	*Minimum Pounds by Grab Test*
Full-Grain	100
Machine-Buffed	150
No. 1 Split	200

These requirements are conservative, but sufficient to show that a sample of leather has the strength necessary for the service intended and also to eliminate tender hides.

SMALL CLEARANCE UNNECESSARY

Larger Bolt-Holes Will Facilitate Assembling Transmission and Engines

As a result of the following comments received by the Society from an engine manufacturer, the standardization of the size of the transmission mounting bolt-holes for the flywheel-housing type of construction was referred to the Transmission Division:

> We have occasionally received complaints that it is a difficult matter to line-up the transmission mounting holes with the tapped holes of the flywheel housing so that the capscrews can be inserted properly. Inasmuch as the holes in the flywheel-housing flange are tapped and will vary slightly, the holes in the transmission flange are in most cases only 1/64 in. larger than the capscrews used
>
> However, these capscrews have no aligning purpose, as a transmission flange has a pilot which fits in the flywheel housing. We can therefore see no adequate reason why these holes should not be made larger. The present practice of some transmission manufacturers is to use a 1/64-in. clearance, others use a 1/32-in. clearance and some, the writer understands, use a clearance as large as 1/16 in.
>
> We can see no objection to a 1/16-in. clearance, as it will facilitate attaching the transmission to the engine and would not affect the holding quality of the joint

In order that the Transmission Division may take proper action in respect to this suggestion, information has been obtained by the Society as to what clearances are used at the present time. It is expected that a report will be submitted at the Annual Standards Committee Meeting covering this subject.

SOCIETY MEETINGS

PRODUCTION MEETING OCTOBER FEATURE

Two-Day National Meeting in Cleveland Expected to Attract Large Attendance

Four meetings crammed with valuable production information, intensely interesting factory visits and an informal Production Dinner constitute the features of the Second National Production Meeting of the Society which will be held in the Winton Hotel, Cleveland, Oct. 25-26. Over 600 production men received the 1922 Production Meeting in Detroit enthusiastically because it gave them new ideas to carry home. The program of the Cleveland Meeting has been planned along exactly these lines; practical usable information will be found in all of the papers. There are ten papers assured for the meeting and these are described briefly in the lists of speakers in another column. A brief study of this program should convince production executives that it will be profitable for them to drop all factory ties and become a part of the Production Meeting.

From the opening of the first session on Thursday morning to the final word at the Production Dinner on Friday evening, all thought will be concentrated on matters of interest to the factory executive. Topics listed on the program are sufficiently diversified to hold interest for nearly all classes of shop executives. Time will be provided for questions and answers following each paper. Some time will also be available for general discussion of the more important topics.

A special effort will be made to start all of the meetings promptly. They will be held in the Rainbow Room of the Winton Hotel, which is especially suited to the staging of meetings of this type. The banquet on Friday evening will be held in the ballroom of the Winton Hotel. Everyone interested in the advancement of automotive production methods is welcome at the meetings; it is not necessary to be an S. A. E. member to secure the privilege of attendance at these particular sessions.

Although all details of the program arrangement have not been set definitely at this time, the following outline will be adhered to:

THURSDAY, OCT. 25

9:30 A. M.—Machine Tool Session
1:00 P. M.—Lunch
2:15 P. M.—Factory Managers' Session
8:00 P. M.—Scientific Management Session

FRIDAY, OCT. 26

9:30 A. M.—Inspection Session
1:00 P. M.—Lunch
2:00 P. M.—Factory Visits
6:30 P. M.—The Production Dinner

HOTEL RESERVATIONS

Cleveland hotel facilities will be taxed during the period of the Production Meeting due to the presence of other large conventions besides the S. A. E. Meeting. It is extremely important that you write to the Hotel Winton and make reservations in advance if you wish to be assured of comfortable quarters. Rates are as follows:

Room with private bath, single, $3.00, $3.50, $4.00, $4.50, $5.00
Room with private bath, double, $5.00, $5.50, $6.00, $7.00, $8.00
Room with private bath, twin beds, $6.00, $7.00. $8.00, $10.00

THE PRODUCTION DINNER

Nothing promotes interchange of experience and the development of new ideas more than social contact between individuals engaged in the same field of endeavor. Broadening of acquaintanceship between men in the production end of the automobile business can best be accomplished by functions such as the Production Dinner. That is the entire purpose of the Production Dinner during the Cleveland Meeting. It will be informal in every respect. There will be entertainment and music while the food is being served.

THE PRODUCTION DINNER

APPLICATION FOR TICKETS

1. All Seats are reserved. Preference as to location will be accorded applications in the order of their receipt.

2. Tables seat eight. If you wish to make up your own party, send in one application for the entire group of tickets. All tickets requested on a given application will be for the same table.

3. The dinner is to be informal and the wearing of evening clothes discouraged.

4. No tickets can be cancelled or refund granted after Tuesday, Oct. 23.

5. Orders for tickets mailed after Monday, Oct. 22, should be addressed to the Society of Automotive Engineers, Winton Hotel, Cleveland, O. Tickets will be on sale at the hotel until 6 P. M. Oct. 26.

(See Over)

PRODUCTION MEETING SPEAKERS

H. F. HARRISON

H. H. Franklin Mfg. Co.

J. BOUTON

Chandler Motor Car Co.

OSCAR A. KNIGHT

Norton Company

RALPH E. FLANDERS

Jones & Lamson Machine Co.

ALBERT E. SHORE

Standard Equipment & Mfg. Co.

E. P. BLANCHARD

Bullard Machine Tool Co.

W. E. JAMESON

Cleveland Automobile Co.

The human element in production. Practical philosophy on the handling of men. Development of the worker's interest in his daily task. Stimulating the worker's powers of concentration to overcome "human element errors."

PERCY S. BROWN

Corona Typewriter Co.

Comprehensive paper covering every detail of production control as applied in the Corona plant. Explains organization system, theory of their production problem and shows how this is met. Description of various forms, schedule boards, and sample graphic control boards.

A. J. OTT and C. L. OTT

American Grinder Co.

Description of a process of grinding gear teeth of the involute form to contours of high accuracy. Methods of inspecting gear teeth for proper form, tooth thickness and spacing.

A. H. FRAUENTHAL

Chandler Motor Car Co.

Factors governing the measurement of "out-of-roundness." Various adverse conditions are found in measuring size variations of cylindrical objects with modern inspection apparatus. Points that have been determined by a close study of this condition will be presented.

Dinner talks will be short and to the point; at the same time they will be highly inspirational. The dinner program will be arranged so that plenty of time will be available for friendly chats after the final drop of the toastmaster's gavel.

Seats at the dinner will be reserved. Tickets will sell at $3.50 each and preference as to location will be accorded applications in the order of their receipt. Members who are planning tables or individual seats should forward the blank at the bottom of this page with their check to the New York office at once.

FINAL ANNOUNCEMENT

Final announcement of all of the details of the Production Meeting will be included in an issue of the Meetings Bulletin which will reach the entire membership about Oct. 15. This Bulletin will be sent to many production executives who are not Society members. Mail us the names of men in your shop.

THE PRODUCTION DINNER

APPLICATION FOR TICKETS

Society of Automotive Engineers, Inc.
29 West 39th St., New York City.

Order of Receipt.....

Gentlemen:—

Please mail me ... tickets for the S. A. E. Production Dinner at the Winton Hotel, Cleveland, Oct. 25. I am enclosing remittance of $..... to cover the cost of these tickets at $3.50 each.

I understand that all dinner seats are reserved and that preference as to location will be accorded applications in the order of their receipt.

I also understand that dinner tickets are not subject to cancellation or refund after Tuesday, Oct. 23.

Mail tickets to address given herewith.

Hold tickets for me at the door.

Signed .....

Address .....

.....

(over)

VINCENT DISCUSSES EIGHT-IN-LINE

Four-Wheel Brakes Also Treated in Talk Before Cleveland Section

J. G. Vincent

Eight-in-line engines, four-wheel brakes and easy steering were the subjects of a comprehensive engineering and mathematical analysis presented by Past-President J. G. Vincent and W. R. Griswold before the Cleveland Section Sept. 17. Attendance records for Cleveland Section meetings were broken on this occasion, there being over 300 present during the technical session and over 150 seated for dinner. The Vincent-Griswold paper, which presents the engineering reasoning underlying the development of the Packard single-eight car, will be found on p. 257 of this issue of THE JOURNAL. The mathematical appendices to the paper will appear in the November issue. Important points raised in the discussion are recorded in the following paragraphs.

Numerous written questions were presented to Mr. Vincent on cards that had been passed through the audience. Answers to these questions occupied a greater part of the discussion period. It developed that a majority of the questions related to four-wheel brakes, the members apparently displaying a greater interest in this feature than in the eight-in-line engine. Asked whether he had considered using only the front brakes for service purposes, Mr. Vincent replied that all the braking effort that could reasonably be gotten was wanted in the service brakes since these are the real emergency brakes, the so-called emergency brake being nothing but a standing brake. In a car that has the ability to accelerate quite rapidly and weighs considerable, maximum brake effectiveness should be provided and obviously it cannot be gotten on two wheels. Also, by distributing the braking effort over four wheels wear is greatly reduced and frequency of adjustment is decreased. In the Packard layout the rear-wheel brakes are also used for the standing brake, but they are operated through an independent mechanism.

BRAKE PRESSURE DIVIDED UNEQUALLY

Pressure is not applied equally to the Packard front and rear brakes, but is divided in the ratio of 45 per cent on the front brakes and 55 per cent on the rear. However, both brakes are applied simultaneously. A maximum rate of deceleration of 20 ft. per sec. can be attained and this effects a stop in 200 ft. from 60 m.p.h. Mr. Vincent remarked that four-wheel brakes take hold more smoothly than the conventional rear-wheel system and rear-axle chatter is avoided. He did not favor propeller-shaft brakes for general service work. He said that very satisfactory four-wheel brakes can be built for the same money as a practical propeller-shaft brake with sufficient strength provided in the rear axle to carry the braking loads.

Mr. Vincent favored internal expanding brakes over those of the external contracting type for several reasons. In the first place, they are housed-in and protected from dirt, and this prevents excessive wear. He believed that external contracting brakes are likely to freeze-up under certain conditions. External brakes are more difficult to adjust, in his opinion, since there are more parts to keep in adjustment, such as the sliding block, the throw, and the top and bottom clearance. He did not believe that it was impossible to design internal brakes so that suitable leverages could be obtained to guarantee efficient brake operation.

FREE-WHEEL THEORY DISPUTED

Some front-wheel braking systems are designed so that the outside front wheel brake releases automatically on a turn, allowing this one wheel to run freely. Mr. Vincent stated that he could see no particular advantage in this arrangement. Geometrical relation of front-wheel brake parts should be such that spring deflection under the braking loads will tend to reduce the braking pressure rather than increase it. This will avoid a violent front-axle chatter that might otherwise be set-up.

The steering-knuckle axis of the Packard axle is set at an angle of 10 deg. from the vertical; theoretically, it intersects the point where the tire contacts with the ground. With the recommended brake adjustment, it is very difficult to lock any of the wheels when driving upon dry pavement. It is possible, of course, and in this case the rear wheels will probably lock first. Mr. Vincent recommended that four-wheel brakes not be made so sensitive that they can be locked easily.

The involute form of tooth is used in the Packard transmission gears, the pressure angle being in the neighborhood of 18 deg. The gears are made of chrome-nickel steel and are oil-treated.

SINGLE-EIGHT ENGINE COMPRESSION

The compression-pressure in the single-eight engine is approximately 75 to 80 lb. per sq. in., this being taken with the engine warm, the engine turning over at 120 r.p.m. and the throttle wide-open. The maximum engine-torque is 2730 lb-in. The complete car in proper adjustment will average between 12 and 14 miles per gal. of gasoline.

Eight-in-line engines are primarily a passenger-car development. Mr. Vincent did not believe that they would be adopted for airplane service. He did predict the passing of the eight-cylinder V-engine in airplane practice, the light high-powered 12-cylinder engine superseding it entirely in military work. It was his opinion that the 12-cylinder aircraft engine could be built with less weight per horsepower than any other type.

AMATEUR CABARET PLEASES

Cleveland's energetic and versatile Secretary, Leo Williams, spiced-up the dinner-hour with musical features. He introduced the Cleveland Four-in-Line, an organization of male choristers whose close harmony drew deserved applause. A young gentleman by the name of Ball contributed several tuneful accordion selections which pleased the assembly. Williams stepped from his secretarial rôle for a brief period and teamed with a young lady in a novel rendition of "That Red-Headed Gal." This naturally brought down the house. Coker F. Clarkson spoke briefly and presented a Scotch story gathered up during his recent European travels. Chairman John Younger presided at both the dinner and the meeting. Several members of the Council were seated at the guest table and enjoyed the meeting thoroughly.

WASHINGTON CANCELS OCTOBER MEETING

The Governing Committee of the Washington Section has sent the following announcement to all members of the Society in its territory, the Council and others interested:

> The meeting of the Washington Section of the Society of Automotive Engineers, scheduled for Oct. 5, has been cancelled as a mark of respect for the members of the Bureau of Standards who, as a result of the recent deplorable explosion, gave their lives in the pursuit of scientific advancement.
>
> Stephen M. Lee — Urban J. Cook
> James E. Kendig — Logan L. Lauer
>
> To the families of these men, the Section extends the deepest sympathies of its members. For those who were injured, it hopes for speedy recovery.
>
> Washington, D. C. THE GOVERNING COMMITTEE.
> Sept. 24, 1923.

HALE ON BALLOON TIRES AT INDIANA

At the Indiana Section meeting on Oct. 11, J. E. Hale, of the Firestone Tire & Rubber Co., will speak for low-pressure or balloon tires, more generally known as "balloon" or "Gyroscopic" tires in spite of efforts to make the more appropriate term current.

Indiana Section members and their guests who did not hear Mr. Hale at Spring Lake will have the opportunity to hear not only what he said then, but also additional material which has been worked out since the summer meeting. The flip chassis at Spring Lake will be a part of the program beginning at 8 o'clock, after an informal dinner at 6:30 at the Severin Hotel, Indianapolis.

HEAD-LIGHTING WITHOUT GLARE

R. N. Falge Discusses Possibilities of Its Accomplishment Before the Metropolitan Section

R. N. Falge

Activities in the Metropolitan Section were renewed on Thursday, Sept. 20, with the first regular monthly meeting of the fall season at the Automobile Club of America, New York City. Importance of Better Automobile Head-Lamps and Proper Adjustment was the topic for discussion. R. N. Falge and W. C. Brown, who read a paper[1] on this subject during the Semi-Annual Meeting of the Society at Spring Lake, elaborated their previous offering and illustrated their remarks with the aid of a demonstrator. The effects produced by placing the bulb at the focal point of the lamp, by moving it forward, backward, above and below that point along the reflector axis, and also by vertical prisms and horizontal prisms placed in the glass, were given a clear demonstration; and following this various lamps taken from the stocks of the best known manufacturers were placed before the lamp and their compliance with or variation from the standards determined for the most efficient illumination was noted. An active discussion followed, which was participated in by Dr. A. W. Devine, Illuminating Engineer of the State of Massachusetts, Mr. Little, of the Electrical Testing Laboratories of New York City, H. B. Maples of the American Automobile Association, and H. S. Carlson, of the Bureau of Standards, City of Washington; a communication also was read from F. H. Ford, of the O. A. Shaler Co. The discussion will be printed in an early issue of THE JOURNAL.

Mr. Falge said that the present construction and easy adjustability of automotive head-lamps, though they had received much attention, are still susceptible of further improvement. He stated that the road would not only be illuminated better, but that objectionable glare could be avoided to a large extent if head-lamps equipped with properly adjusting the headlamps was in service, as [illegible] and far-reaching improvement would be effected. Adjustment requires best of focusing and best of centering the lamps. Less than one third of the cars examined with the equipment of the laboratory were centrally placed by the manufacturer. Inaccuracies of adjustment of the filament are compensated for by placing a lens over the lamp, and by tilting it. Type of lens was described that will compensate for universal inaccuracies in the position of the filament and at the same time distribute the light effectively, converging or diverging the rays laterally while maintaining the top or cut-off substantially at the level of the head-lamp. As the maximum intensity should be placed as near to the top as possible in order to produce the best illumination of the roadbed, and as the eye accommodates itself slowly to changes of intensity, the lens takes advantage of these characteristics by spreading the light in each zone by different amounts.

Spot-Lights

Mr. Falge added that in driving to the Summer Meeting at Spring Lake his car was equipped with two spot-lights in addition to head-lamps and that the spot-lights were turned off when other cars approached. Dr. Devine remarked that spot-lights could not be used in Massachusetts.

Needed Improvements

Dr. Devine further stated that greater accuracy in the production of reflectors is very much needed. He felt that with that accomplished and the elimination of necessity for adjustment of the bulb in the lamp, all that would be necessary in the proper installation of head-lamps would be to tilt them a proper amount. He pointed out that it is essential that in aiming the head-lamps the rear passenger load or its equivalent be in place. He referred to the fact that 11 Eastern States have been proceeding in conference with the purpose of so harmonizing conflicting laws of bordering States that they will not cause inconvenience to motorists.

Conditions in Massachusetts

Stating that the head-lamp adjustment is the most difficult thing to attain, the relatively severe enforcement of head-lamp laws in Massachusetts was taken up. There are 12 inspectors in the field there now and 12,000 complaints are in hand. Last year the number of fatal accidents during the night time was reduced 50 per cent by legal enforcement and regulation, but the headway made was not permanent because during two months this summer fatalities increased 50 per cent as compared with last year. This has resulted in the institution of another campaign of regulation and examinations of head-lamps are being made at the rate of 20,000 per month.

One further point that Dr. Devine made was that the reflectors must be maintained in good condition to secure good illumination, the reflectors becoming discolored if damp for a short time. In Massachusetts the motorists are given sketches showing a cross-section of properly and of improperly focused head-lamp illumination. They are told to stand their cars 25 ft. from a board and secure the desired focus and then tilt the lamps down the required amount. Eight hundred different stations in Massachusetts have been authorized by the State to adjust head-lamps.

The Motorist's Position

Mr. Maples asserted that lamps with different kinds of adjustment would not stay in adjustment because of the poor quality of either the lamps or the sockets; that not the motorists but the manufacturers are to blame; that the principal problem is to determine standards for the lamps and for the sockets.

Work of Bureau of Standards

Mr. Carlson stated that the Bureau of Standards and the Illuminating Engineering Society had cooperated in the preparation of specifications and that 27 different head lighting devices had been accepted as satisfactory, but that these are of no value except when properly adjusted. After testing 400 cars only 5½ per cent were found to conform to requirements. Letters from 50 automobile manufacturers showed great diversity of opinion as to what should be done. Head-lamps may be thrown out of adjustment even before the cars are delivered to customers.

Mr. Carlson urged that the matter of securing proper adjustment have the hearty cooperation of all concerned. On behalf of the Bureau of Standards, he is now working through local trade associations and dealers. Screens for use in securing proper adjustment, like those installed by

[1] Text [illegible] page 4[illegible]

the Bureau in the District of Columbia, are furnished. He felt that the Society should take a very active part in this matter, through its Sections particularly, and that proper adjustment should be available to all at proper stations for a nominal fee. He advocated a system by which some member of the Society should be personally responsible for improvement of conditions in each part of the Country. The American Automobile Association and the National Motorists' Association have printed and distributed proper instructions. Safety Councils and those charged with the enforcement of the law should naturally take part in the proceedings.

Mr. Ford suggested that it would assist the user if illumination were expressed in such terms as "bright moonlight," instead of candlepower, focal distance, and the like. He said that most instructions for adjusting head-lamps are not intelligible to the motorist and that the latter does not comprehend what he is trying to get, and consequently cannot get it.

Replying to questions, Mr. Falge said that the Society is now endeavoring to bring about practice in the construction of head-lamps that will prevent the lenses from turning from their proper position for satisfactory illumination; that "fixed" adjustments of bulbs could not be depended on entirely because a very slight change in adjustment produces a large variation in the distribution of light; that it would be possible to compel motorists to keep the head-lamps in adjustment if they knew they would be penalized for not doing so; that in Massachusetts the proportion of complaints was 3 for insufficient light to 1 on account of the lens. Adjusters are employed in Massachusetts who notify drivers to adjust certain parts and give them cards that must be o.k'd. Reports show that 36 per cent of the head-lamps inspected had twisted lenses, 73 per cent were out of focus, and 70 per cent had tilted reflectors.

Chairman Myers, in summing up the discussion, concluded that the two important points to be considered are (*a*) giving the users in general some simple method of checking-up in order to get proper adjustment, and (*b*) securing greater refinement in the manufacture and assembly of head-lamp equipment to preserve alignment and focus.

Procedure for Head-Lamp Adjustment

Supplementing his original paper, Mr. Falge submitted the following suggestions for adjusting head-lamps:

(1) *Use Only* 21-*cp. Gas-Filled Head-Lamp Bulbs.*—Lamp-bulbs should be uniform and efficient in performance throughout their life. They should have highly concentrated filaments to give the minimum beam divergence. The filaments should be placed accurately with respect to the locking-pins and to the axis of the base in order to minimize beam distortion. They should not sag in service

If new lamps do not give a fairly white light with the engine running at a speed corresponding to 18 or 20 m.p.h., have the battery inspected at a service-station before proceeding with the adjustment. If lamps have been burning-out at short intervals, have the connections from the generator to the battery inspected, and replace any socket, fuse or connection that is found to be defective

(2) *Polish Reflectors with a Soft Cloth Dipped in Powdered Lamp-Black.*—Fogged, rusted or defective reflectors should be replaced with new ones; they should not be replated. If the gasket cord, which is provided to make an air-tight seal between the lens and the reflector, is loose, fasten it back in place with shellac

(3) *Focus the Lamps in the Reflectors.*—Some means, which can be determined upon examination, is always provided for moving the lamp forward and backward in the reflector. Adjust the lamp until the filament is so placed with respect to the reflector that the spot which is thrown on a vertical surface 25 ft. ahead of the car will be of the minimum size and approximately round. With fluted reflectors that spread the light to either side, the filament will be properly placed when the spot is shallowest in the vertical dimension. One point that should be kept in mind in either case is that the top of the beam should cut-off as sharply as possible, and results frequently can be improved by turning the lamp over in the socket when the beam is not satisfactory as first installed

(4) *Install Redirecting Equipment.*—When the ordinary redirecting lens is used, be sure that it is placed in the head-lamp door so that the wording on it reads properly from the outside and that it is fastened securely so that it cannot rotate away from a truly vertical position. When fluted reflectors are used, they in themselves accomplish the spreading of the light and require only a plain cover-glass. It is important that flutes be in a truly vertical position

Install one head-lamp door, with the glass properly fastened in it, on the head-lamp and hold the other door loosely in front of the other head-lamp in the proper position. Cover first one beam and then the other. The spots from both, as seen on the vertical surface, should look practically the same. If they are noticeably different, it means that the focus has been disturbed in installing the door, possibly due to the fact that the reflector moved back on the springs and the lamp position remained the same. Re-focus the lamp so that both beams will look the same. Install the other door and re-focus in the same manner

(5) *Aim the Beams.*—Place the car, with the rear seat fully loaded, on a level stretch with a

Schedule of Sections Meetings

OCTOBER

4—Detroit Section—Rotary Valves—E. Bournonville
Rotary Disc Valve—O. D. Heavenrich
11—Indiana Section—Low-pressure Air-cushion Tires—J. E. Hale
12—Mid-West Section—Fundamentals in Engineering—C. F. Kettering
18—Metropolitan Section—Brakes—H. M. Crane
23—New England Section—Duralumin—A Discussion of Some of Its Applications—R. W. Daniels
24—Milwaukee Members Meeting—City Planning in Relation to Traffic
29—Buffalo Section—Problems in the Construction of Low-Pressure Tires—J. F. Palmer
Cleveland Section—No meeting this month because of National Production Meeting in Cleveland, Oct. 25-27

garage floor or other vertical surface 25 ft. ahead. Sight through the center of the rear bumper over the radiator cap and mark a point on the vertical surface at the same height as the lamp centers. Draw a horizontal line through this point and on it locate points at the right and left of the center line directly ahead of each head-lamp.

On most makes of car a universal-joint or a slot in one of the bolts fastening the head-lamp to the fender or to the frame is provided to facilitate aiming. On a few cars, such as the Ford, it will be necessary to bend the head-lamp bracket. With one head-lamp covered, center the spot from the other on the vertical line through the point *A* directly ahead of it, and set the beam to the point where its top or cut-off is just below the horizontal line *AA*. In a similar manner the other head-lamp should be aimed on the point *A* directly ahead of it.

When adjustments are made properly, a shallow band of light will be thrown upon the vertical surface with its top just below the horizontal but with a low intensity diffused light above the horizontal line. The road surface will be so well lighted that the motorist can pass other cars conveniently and safely. It is possible that oncoming drivers may at times signal to the motorist to dim. Intolerable glare has been so common in the past that whenever drivers see head-lamps illuminated with a white light they anticipate trouble.

Under a few conditions glare results even with head-lamps properly adjusted as, for example, when a car is coming over a rise. Under such conditions, drivers should, of course, dim the head-lamps for both cars and pedestrians.

(6) *Maintenance.* If you can distinguish the faces of persons in approaching cars by the light from your own head-lamps, your lights are glaring decidedly. At reasonable intervals the adjustments should be checked by throwing the beam against a vertical surface or viewing it from about 100 ft. ahead of the car in order to be sure that vibration and handling have not changed the focus and aiming materially. The head-lamps should, of course, be re-focused and re-aimed each time a lamp is renewed.

Proper head-lighting is impossible if the equipment is not kept in reasonably good condition. The time it takes to wash the *outer* surfaces of the lenses now and then is well spent. Each time a lamp is renewed, and oftener if necessary, the reflectors, the lamps and the inner surfaces of the lenses should be cleaned carefully.

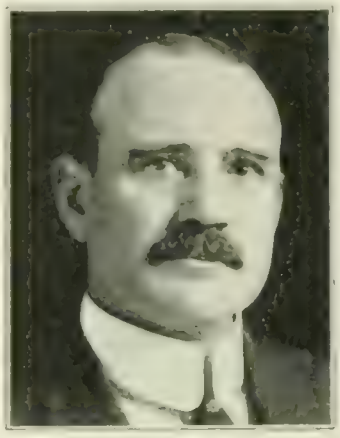
Metropolitan's next meeting will be held at the Automobile Club of America, 247 West Fifty-fourth Street, New York City, on Oct. 18. The topic is Brakes, and H. M. Crane is the speaker scheduled. The customary informal dinner will be served at 6:30 p. m. and the meeting will start at 8 o'clock.

DURALUMIN—SOME OF ITS APPLICATIONS

The popularity of plant inspection these Fall days has spread to the New England Section. The next meeting, scheduled for Oct. 20, will begin with an inspection of the Rauch Machine Tool Co.'s plant in Springfield, Mass. After a dinner at 7:00 in the Highland Hotel, Springfield, the evening technical session will have as speaker R. W. Daniels of the Rauch Machine Tool Co. His topic will be Duralumin and Discussion of Some of Its Applications. With the famous duralumin motor car on the floor, Mr. Daniels should make the high standard of New England section programs.

C. W. NASH MID-WEST SECTION HOST

President of Nash Co. Says Engineers Deserve More Credit for Benefits of Auto



C. W. Nash

Mid West Section made an excellent start of the new Section year in its visit to the plant of the Nash Motors Co. at Kenosha, Wis., on Sept. 21. From the morning golf tournament, through the plant inspection personally conducted by C. W. Nash, to the dinner in the evening at which Mr. Nash made a short address, the Mid-West Section members felt that no pains had been spared to make their visit a red-letter occasion.

The laurels in golf for low gross score went to Harold Long, purchasing agent of the Nash company. H. J. Mellum, secretary of the company, won second prize for low net, and Walter J. Buettner, the Mid-West treasurer, carried off third prize. A special feature not on the program was a ball game between the Nash and Simmons teams which was won by the Nash nine, 2 to 1.

Mr. Nash met his guests at luncheon and remained with them for the rest of the day. They were unusually fortunate in having him personally conduct the inspection of the plant in the afternoon, for he has a remarkably intimate acquaintance not only with all his men, but also with all the operations of his factory.

At the dinner which closed the visit, Mr. Nash expressed his belief in the engineering fraternity and his conviction that engineers should receive a larger share of the credit for the health and happiness which the motor car has brought to so many people. Mr. Nash attributes his success to close contact with his men and welcomes opportunities to reach engineers more intimately. The 50 Mid-West men present elected Mr. Nash the first honorary member of their Section, in appreciation of his expressed desire of securing better cooperation between the engineering and the production phases of the automotive industry.

The October meeting of the Mid-West Section will maintain the standard set by the Kenosha trip. C. F. Kettering, president of the General Motors Research Corporation, will speak on Fundamentals in Engineering at the meeting set for 8 o'clock on Oct. 12 at the Western Society of Engineers, Chicago, after the customary informal dinner at 6:30.

AIR-COOLING UNPOPULAR IN DETROIT

Section Opens Season Auspiciously Despite Frigidity of Cooling Mediums

Air-cooling and water-cooling have their proper places in motor vehicle design, but when they start on a rampage and attempt to make merry amidst a sport outing of the engineering fraternity, that is quite another matter. Detroit Section officers had planned an attractive program of swimming and boating events as a feature of the Section outing held on Sept. 10 at the Detroit Boat Club. On the particular afternoon under discussion, the air and water temperatures reached a point on the Fahrenheit scale that is far from conducive to comfort, especially when one is immersed in the colorful waters of the Detroit River. Just to prove the courage of the committee which had conceived the marine program, George McCain, its chairman, splashed about in hopes of selling the idea to others in the assembly, but without appreciable success. R. H. Weinert bolstered up the

H. M. Rugg C. H. Brennan G. L. McCain
Responsible for Detroit Section's Social Meeting

nautical program by cutting capers in his amazingly active motor boat "S. A. E." He found many willing riders in the assembly, particularly those of feminine gender. If maneuverability counts in supplying thrills to motorboat followers, the "S. A. E." takes top rank.

Temperatures bordering on frigidity had a beneficial effect on the other features of the program and the net result was a very successful social meeting. Over one hundred were seated at the dinner table and partook of the Boat Club chef's handiwork. This dusky individual soon announced that "the cupboard was bare" and saxaphone bleatings enticed the members and their ladies into the twirling of merry steps upon the ballroom floor. Acquaintance and congeniality were promoted by the injection of several Paul Jones and dancing continued for several hours. The number of ladies who expressed curiosity concerning the scheduling of a similar occasion in the near future serves as supporting evidence that the Detroit Section season was opened auspiciously.

Next Detroit Section Meeting

Various types of rotary and sleeve-valve engines will be described and discussed at the next meeting of the Detroit Section Thursday evening, Oct. 4. E. Bournonville will read a paper on valves of the rotary-tube type and Osmond D. Heavenrich will present the advantages of the rotary-disc valve. Well-known authorities on sleeve-valve engines are expected to attend and give short talks on the latest developments in this type. Of course the poppet-valve supporters will be on hand to defend the conventional practice now followed by a majority of the car producers. The combination of these several viewpoints on one program should produce an active and interesting discussion, to say the least. Detroit Section meetings are held in the General Motors Building and are preceded by an informal supper at 6:30. Presentation of papers starts promptly at 8 o'clock.

LOW-PRESSURE TIRE CONSTRUCTION

J. F. Palmer of the Hewitt Rubber Co. will speak on Low-pressure Tire Construction at the Buffalo Section meeting on Oct. 29. Mr. Palmer's experience—one of the widest in the industry—qualifies him to speak with authority on tire matters. The meeting, which will begin promptly at 8 o'clock, will be held in the Statler Hotel.

ANNUAL MEETING PAPERS WANTED

Members who are planning to present papers on the program of the Annual Meeting in Detroit next January should communicate with the New York office of the Society without delay. It is planned to make this meeting one of the most comprehensive ever held by the Society. There will be sessions on nearly every phase of automotive engineering; fuel, engines, chassis, bodies, production, aeronautics and other important topics will be treated.

The Meetings Committee is anxious to receive papers on any subject of general interest for consideration as Annual Meeting contributions. In submitting requests for a place on the program, give a reasonably complete description of what you intend to present. But, most important point of all, acquaint the Committee with your desire to appear on the program without waiting for an invitation.

WHEEL ALIGNMENT DISCUSSED

Successful Opening Session of New England Section

John F. Duby

Over 60 members and guests were present at the session of the New England Section of the Society held in Boston at the Buckminster Hotel on Sept. 11. Chairman R. E. Northway told of the plans for the season, the next meeting being scheduled to be held in Springfield on Oct. 2.

The September meeting was preceded by a dinner at which the best of good fellowship prevailed.

John F. Duby of Boston gave a valuable analysis of the features to be considered in wheel alignment and the troubles attributable to misalignment. He said that he had in his long experience found considerable confusion on the subject among engineers. Mr. Duby's purpose was to give a short, easy method of calculating and allowing the correct setting for all cars to assure good steering and minimum tire wear. He stated that it was not necessary to sacrifice the tire to secure good steering. Wheel alignment is seriously affected by axles, tie-rods, king-pins, radius-rods, steering-arms, steering-gear, and spring suspension plays an important part.

The rear wheels should be parallel in every way; that is, each wheel should revolve in a perfectly true circle. Some causes for misalignment of the rear wheels are bent axle-housing, improperly adjusted radius-rods and loose spring-clips.

There are very few cars on which the front wheels are the same distance apart at their centers as the rear wheels, and very few, if any, cars on which the front wheels are parallel to each other. They are closer together at the bottom than at the top, and the front axle is set at an angle to cause the king-pins to be further forward at the bottom than at the top. It is generally agreed that these conditions are correct; the disagreement arises over the reasons and the proper amount to be allowed.

The propulsion of the car tends to cause the front wheels to toe-out. This is one of the principal reasons for toeing them in. The purpose of camber is to bring the contact of the front tires on the ground directly under the king-pins. Also, the camber counteracts the effect of the weight on the spindles. As the camber increases, the tendency of the wheels to toe-out decreases. Large wheels require more toe-in than small ones. The author expressed the opinion that the proper amount of toe-in is from ⅛ to ¼ in., measured between the tires at points 9 in. from the ground. Also that cars will steer well with from 1 to 3 deg. of camber, but that there is undue tire wear with more than 2 deg. The object of tilting the front axle backward is to secure caster effect on the wheels, the tire contact with the ground being behind the line drawn through the king-pin axes. Insufficient tilt causes the wheels to pull hard in turning corners with the car. The front wheels should be the same distance apart as the rear wheels, at the bottom.

Wheel alignment should be measured after mounting bodies on cars, to assure proper axle tilt.

A lively discussion was had as to the effect of wheel alignment on tire wear and as to front wheel wabble.

Applicants *for* Membership

[redacted]

[redacted]

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Aug. 10 and Sept. 10, 1923. The various grades of membership are indicated by (M) Member, (A) Associate Member, (J) Junior, (Aff) Affiliate, (S M) Service Member, (F M) Foreign Member, (E S) Enrolled Student.

[redacted]

ANDERS, A. SIDNEY (E S) student, University of Michigan, Ann Arbor, Mich., (mail) 2229 Hughes Terrace, *Detroit*.

AITKEN, LEON L. (J) chief tool designer, Fuller & Sons Mfg. Co., Kalamazoo, Mich., (mail) 317 Perry Court, *Flint, Mich.*

ANDIAN, PETER ARCHIE (E S) student, University of Cincinnati, Cincinnati, Ohio, (mail) 2308 Clifton Avenue.

[redacted]

BOND, MILTON (M) chief engineer, Stacey Motor Carriage Co., Newton, Mass., (mail) 196 Prospect Street.

DONALDSON, W. R. (J) designer, General Motors Truck Co., *Pontiac, Mich.*

[redacted]

GROSS, EDWARD H. (A) sales manager, Downing Carburetor Corporation, Bridgeport, Conn., (mail) 2156 Lenox Avenue, *Detroit*.

[redacted]

HAMILTON, E. H. (A) sales engineer, Hampton-Watson & Cia., Casilla 702, *Buenos Aires, Argentina*.

HAVERSTICK, GEORGE R. (M) assistant engineer, United Motors Products Co., *Grand Rapids, Mich.*, (mail) 412 Crescent Street, Northeast.

HORI, HISASHI (F M) chief engineer, Yanase Automobile Co., Ltd., 2 Jonigamicho, Kojimachiku, *Tokyo, Japan*.

[redacted]

LANGER, JAMES U. (A) engineer, Standard Oil Co., *Portland, Ore.*, (mail) 149 Grand Avenue.

[redacted]

MACK, WILLIAM (A) sales manager, Borg & Beck Co., 920 South Michigan Avenue, *Chicago*.

MICHELIN, MARCEL (F M) manufacturer, Michelin & Cie, *Clermont Ferrand, France*.

[redacted]

PATON, CLYDE U. (A) teaching assistant in mechanical engineering, University of Michigan, *Ann Arbor, Mich.*, (mail) 1121 Church Street.

[redacted]

POLETTI, CAPT. ALLEN W. (S M) shop superintendent, Quartermaster Corps, *Camp Normoyle, Tex.*

POLTI, R. C. (A) engineer, Stromberg Motor Devices Co., 250 West 57th Street, *New York, City*.

[redacted]

RAWLINS, EDWARD L. (A) sales engineer, Arthur L. Eaton Co., 3769 Motordo Avenue, *Los Angeles*.

REIS, BEN A. (M) chief engineer, truck equipment division, Edward E. Exton Co., 735 Folsom Street, *San Francisco*.

SAUNDERS, LAWRENCE P. (M) experimental engineer, Harrison Radiator Corporation, Lockport, N. Y., (mail) 10-126 General Motors Building, *Detroit*.

[redacted]

STILLSON, HERBERT L. (A) vice-president and director of sales, Studebaker Motor Corporation, *South Bend, Ind.*

[redacted]

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIII November, 1923 No. 5

Chronicle and Comment

The Production Meeting

MOST of the papers read at the second national Production Meeting of the Society are printed in full in this issue of THE JOURNAL. Illustrated reports of the four sessions and Production Dinner held in Cleveland Oct. 25 and 26 will be found commencing on p. 429. To say that the meeting was enthusiastically received, is putting it mildly. The attendance of production executives in gratifying numbers served as further evidence that this phase of the Society's work is appreciated.

The Production Meeting is now an established institution and will be included permanently in the meetings activities of the parent Society. In addition, several of the Sections are devoting a part of their meetings to production matters. The Detroit Section has announced the scheduling of two monthly meetings in the future, one of which will treat manufacturing problems exclusively. Thus we proceed to the inevitable ideal of true cooperation between the designer and the constructor.

Automotive Standardization

ALTHOUGH the Society's Standards Committee is the recognized standardizing body in the automotive industry, its work is supplemented and strengthened by other organizations having a national status. Briefly, these organizations and their objects are

(1) American Engineering Standards Committee, a national clearing-house for standards

(2) Division of Simplified Practice, a division of the Department of Commerce organized by Secretary Hoover to aid in reducing standards to practice

(3) Automotive Simplified Practice Committee, a committee representative of automotive associations organized at the request of the Division of Simplified Practice, its object being to encourage the adoption of automotive standards in future production

In addition to these, there are a large number of technical societies and trade associations having a limited scope within the automotive industry with which the Standards Committee, through its Divisions, is actively cooperating.

Maintenance Problems

AN invitation has been extended to our members by the National Automobile Chamber of Commerce to participate in its Service Managers Convention at Dayton, Ohio, Nov. 20 and 21. Meetings devoted to topics that are of equal interest to the designer and the service-man will be held in the morning and afternoon of both days. Papers on the following subjects will be read and discussed: evils of head-lamp dimming; instructions on head-lamp adjustment; engineering lessons taught by the flat-rate system; educating the public to combat the evils of crankcase dilution.

One session will include a discussion of what the engineer can do to simplify electrical repairs. Designing cars to eliminate the need of costly special tools for making repairs will be another important topic. These meetings present an excellent opportunity for the engineer to learn what troubles are encountered generally in the maintenance of motor vehicles. Thus he will be enabled to combat them with improvements that can be incorporated in future designs.

Non-Member Affiliation with Sections

THE Governing Committees of the Cleveland, Detroit, Metropolitan and Washington Sections of the Society have gone on record as being favorable to the establishment of some form of local Section membership that will be open to men who are not members of the Society. Such local Section members would have no privileges in the parent Society and would not receive its publications; they would merely be entitled to the privilege of attending the meetings of the Section with which they became affiliated.

In this connection, a resolution approved by the members present at the October meeting of the Metropolitan Section is representative of the plan being agitated.

> WHEREAS, it will be of advantage to the Metropolitan Section to take in Section members to be known as Associates, these men not being members of the Society, but nevertheless men who may greatly profit by the contact and association with the Metropolitan Section, and whose experience and discussion may correspondingly be of benefit to the Metropolitan Section, be it

Resolved, that it is advisable to have the active participation and financial support of the large number of men in this district who either are not eligible as regular members or who could not reasonably be expected to become members of the Society to join the Sections, and that the Council of the Society of Automotive Engineers is hereby requested to authorize suitable Associate Section membership at $5 per annum.

To become operative, this form of participation in local meetings must receive the approval of the Council of the Society before it can be incorporated in the Constitution and By-Laws of the Sections.

Combined Society and Sections Dues

CONSIDERABLE discussion has been had among various members of the Society who are connected with the work of the Sections, on several points raised with regard to the methods that will result in the most satisfactory and valuable Sections activities. As some amendments to the Constitution of the Society may be proposed at the Business Session of the Annual Meeting to be held in January, attention is called here to a resolution that originated in the Metropolitan Section, so that the members can have an opportunity to study in advance the questions involved. The resolution, as approved by the members of the Metropolitan Section present at the October meeting of that Section, is as follows:

WHEREAS, the main activities of the Society of Automotive Engineers are being carried on by its Sections, and the Section Officers are already burdened with all the detail they can reasonably be asked to carry, and

WHEREAS, larger funds are necessary to carry on the Section activities properly, and these should be raised from among those Society of Automotive Engineers members who directly or indirectly enjoy the results of the Section activities, therefore be it

Resolved, that it is advisable to increase the annual dues of all but Student members of the Society from $15 to $20; that the increase of $5 includes a Section membership, and that this sum be credited to the Section in which the individual resides or makes his business headquarters. Further, that the dues for a Society member residing and having his place of business more than 30 miles from the city in which the Section has its headquarters be $15, unless such Society member desires to become a Section member.

The dues of members of the Society are, of course, specified in its Constitution and cannot be changed except by proper amendment of that document. At the present time the annual dues for all grades of Society members are $15, except in the case of Service, Foreign and Junior members whose annual dues are $10.

Motor Vehicle Speeds

AS to the technical questions involved in speed limits for motor vehicles, it is believed that the recommendations of the Joint Committee on Uniform Vehicle Laws can safely be adopted. The speed limits are as given in the next column.

Maximum Weight, Including Gross Weight of Vehicle and Load	Open Country Highway	Suburban Street	Urban Street
VEHICLES DESIGNED FOR CARRYING NOT MORE THAN SEVEN PASSENGERS			
6,000 lb.	30 miles	20 miles	15 miles
OTHER VEHICLES EQUIPPED WITH PNEUMATIC TIRES			
6,000 lb.	25 miles	20 miles	15 miles
8,000 lb.	25 miles	20 miles	15 miles
12,000 lb.	25 miles	20 miles	15 miles
16,000 lb.	25 miles	20 miles	15 miles
20,000 lb.	25 miles	20 miles	15 miles
24,000 lb.	25 miles	20 miles	15 miles
28,000 lb.	25 miles	20 miles	15 miles
VEHICLES EQUIPPED WITH SOLID TIRES			
4,000 lb.	25 miles	20 miles	15 miles
8,000 lb.	20 miles	18 miles	12 miles
12,000 lb.	18 miles	15 miles	12 miles
16,000 lb.	16 miles	15 miles	12 miles
20,000 lb.	15 miles	15 miles	12 miles
24,000 lb.	15 miles	15 miles	12 miles
28,000 lb.	15 miles	15 miles	12 miles

The recommendations of the committee are based on a careful survey of the existing traffic regulations throughout the country, considered in the light of present technical knowledge. The speeds recommended are, of course, intended to be actual limiting speeds under the existing traffic conditions specified, namely, open road, suburban streets and urban streets, and it is assumed that the law will be strictly enforced. There is no question that these speeds are *perfectly safe* for vehicles which are in proper mechanical condition, driven on roads which are suitably surfaced and dry. To actually enforce speed-limits slower than this would work an economic injustice not so much on the user of motor vehicles as on the whole community, since the ultimate cost is always paid by the consumer. Maximum safe speed is the essence of highway transport economy, and vehicles are constantly being developed toward increasing their safe speeds.

In the last analysis, enforcement of any regulation of this kind depends upon its reasonableness. If the average conservative driver does not consider the regulation reasonable, no practicable amount of policing will serve to enforce it, particularly if it interferes with business.

There is a phase of the safety problem which is much more serious than the regulation of maximum speeds. This is regulation of the speeds at which vehicles are usually operated when the traffic and other conditions require special caution. Some of these conditions are:

(1) Roads wet or covered with ice or snow
(2) Hidden crossings or corners with bad visibility
(3) Vehicles with defective or inadequate brakes
(4) Vehicles overloaded beyond their capacity

Safety depends almost entirely on the ability of the driver to stop within the clear space available. No speed is safe unless the driver can be sure that he has enough clear road ahead in which to stop before anything can get in his way. At 25 m.p.h. a vehicle fitted with pneumatic tires and suitable brakes, and operating on a dry road, can be stopped in from 50 to 75 ft. If the road is wet or icy, the distance required may be three or four times as great. A speed of 15 m.p.h. on the wet road is probably more dangerous than 20 m.p.h. on the dry road.

Obviously, any attempt to meet these conditions by imposing unreasonably low speed-limits can be only a failure. A speed-limit such as 10 or 15 m.p.h. on the open road would be an absurdity and an economic crime, yet under such special conditions as those cited above such speeds should be and are actually adhered to by all competent drivers. It is believed that the only sort of traffic regulation which can meet these conditions is one which will place the responsibility on the driver by requiring him to keep down to speeds from which he can always stop within distances which are determined by the local conditions. Such a regulation could be enforced by empowering traffic officers to demand that vehicles be brought to a stop at any time within a certain specified distance, these distances, rather than the speeds, to be incorporated in the traffic rules.

The Application of Conveyor Equipment to a Small Production Plant

By H. P. Harrison[1]

Production Meeting Paper *Illustrated with* Photographs

TO install conveyors in a going automobile manufacturing plant of moderate size, without interrupting production, and with a minimum amount of rearrangement of the plant and an investment commensurate with the saving to be effected, was the problem, the solution of which is herein described. The conditions that determined whether power-driven or gravity-actuated conveyors should be used are discussed and the various types required for handling raw stock, for machining operations, for sub-assemblies and for finished assemblies are indicated. Among the operations for which conveyors were found particularly advantageous are those of handling cylinder castings from the storage of raw stock to the stockroom for finished parts; carrying cylinders between various machining operations and from the inspection bench to the storeroom for finished cylinders; machining transmission cases; carrying rear-axle gearcases through machining operations and delivering them to the starting end of the axle-assembling line; handling parts between departments and machines; assembling transmissions, engines, and front and rear axles; carrying axles to the washing and paint-spraying machines, thence to the chassis assembling line; handling the trimming of open bodies; the final conveying of chassis and finished cars; and handling the finished cars through the final-inspection and touch-up operations. The conclusion reached is that the use of conveyors not only pays, but pays well.

[1] Master mechanic, H. H. Franklin Mfg. Co., Syracuse, N. Y.

Fig. 1—Feeding End of Cylinder Elevator

Fig. 2—Delivery End of Cylinder Elevator

IN attempting to adapt rapid production methods to the comparatively small production plant the engineer is at once faced with the question, how far conveyor equipment can be applied to his problem. It is necessary first to determine whether the plant has a production large enough to make the installation advisable. In determining the practicability of installing conveyors it is necessary to consider the arrangement of the plant in its present form and the question of possible rearrangement, without too great a cost, in order to allow the material to progress in its logical sequence. The majority of plants that are brought face to face with this problem have been built up in a series of units, as production requirements have increased, in such a way that the department arrangement has been the result rather of the addition of buildings than of the outgrowth of a definite plan for economical production. It may safely be said that there is no plant manufacturing automotive parts that is too small to consider the installing of some conveyor equipment as an aid to cost reduction. The question, how far the installation of conveyors

should be carried, is a matter that can be determined only by a careful study of each individual case.

The equipment of the Franklin Company and the way in which they were carried out are shown in the accompanying illustrations. In considering the problems at the Franklin plant there were several important requirements that had to be fulfilled in making the conveyor installation:

(a) An hourly schedule of from 20 to 60 cars per day
(b) A minimum amount of plant rearrangement
(c) An investment commensurate with the saving to be effected
(d) Ability to make the installation without interrupting production

Before we had given the matter serious thought we started out along the lot system of production, and naturally in order to use conveyor equipment in the several departments it was necessary first to abandon this practice. The various operations must be balanced in such a way that each work-station along the conveyor line has, as nearly as possible, the same time-period as every other station. The type of conveyor selected was intended to meet, as closely as possible, these requirements.

It might be well at this point to note one fact that we have since learned enters largely into determining whether the conveyor shall be power-driven, or simply hand-operated by gravity. In installing several conveyors we first selected a power-driven unit for conveying machined parts and assembled parts between the various machines upon which the operations were performed. These conveyors have since been removed and replaced with others of the gravity type. The reasons for the failure of power-driven conveyors in the locations referred to will be explained more in detail later, but it can safely be stated that for the average plant of small production it is not practicable to use power-driven conveyors where the operations are not performed directly on the conveyor lines.

Fig. 1—The Present Double Gravity Line for Handling Cylinders

A discussion of the conveyor installation at the Franklin plant will probably be made clearer by illustrations. The subject, accordingly, will be treated in the following order: (*a*) Raw-stock-handling conveyors; (*b*) conveyors for machining operations; (*c*) conveyors for sub-assemblies; and (*d*) conveyors for finished assemblies. This, of course, is the logical order in which the stock is progressed through the plant.

The first installation is the handling of cylinder castings from the storage of raw stock to the stockroom for finished parts. Fig. 1 shows the feeding end of the cylinder elevator, the function of which is to elevate the cylinders from the basement floor to the third floor of the same building and deliver the castings to the feeding end of the cylinder-machining line. The elevator itself is automatic in operation and is arranged to pick up the cylinders four on a pallet, without the attention of an operator. The cylinders are delivered on a curved section of gravity conveyor on the third floor, as shown in Fig. 2. The section of gravity conveyor in the foreground is fitted with an automatic electric switch, which stops the operation of the conveyor as soon as 4 loaded pallets rest on it, and sets the conveyor in operation again as soon as those pallets have passed off. This arrangement prevents the piling up of cylinder castings at the delivery end of the elevator. Before installing the cylinder elevator it was necessary to truck the castings several hundred feet horizontally, from their storage space to an elevator, bring them to the third floor and repeat the horizontal travel in order to deliver them at the point where the machine operations began. The elevator, of course, removes any necessity for this handling.

Conveyor for Carrying Cylinders

The first conveyor that we installed, to carry cylinders between the various machining operations, is shown in

Fig. 3. This conveyor is composed of an endless belt along which are interposed sections of roller conveyor under which the belt itself passes, thus allowing the cylinders to collect in certain quantities at the points occupied by the rest stations. The purpose of this installation was to move the cylinders mechanically from one operator to another and still allow some elasticity with regard to the number of cylinders carried between operations. We had already found it impossible to balance exactly the time required for each operation or to combine the operations so that the time would approach the required unit; and the work-station idea seemed to be the logical method of allowing for this discrepancy of time. When the system was put into operation we discovered at once that we could not exert sufficient driving power on the belt to pull it through the rest stations, which I believe numbered 14 at that time. The internal friction of the belt, occasioned by so

Fig. 5—Gravity Line for Transmission Machining Line

many bends around small-diameter rollers, could not be overcome by the surface contact of the belt with the driving pulley. Midway of the machining line is a group of internal grinders, 10 in number, all of which had to be served with unground cylinders. The operators of these machines had to have some means of getting rid of the cylinders after they had been ground. Here again we found that the belt idea was far from ideal for accomplishing this result; in fact, we actually had a single-track road on which to handle a double line of traffic. This conveyor was kept in operation but a short time, as we immediately began a re-analysis of the job to determine the proper type of conveyor to overcome the troubles of this nature. In Fig. 3 you will note a large number of stock boxes along both sides of the conveyor, in which it was necessary to store a small reserve supply of cylinders in advance of each operation so that, in case of minor shutdowns, the operators would not be without stock.

Fig. 4 shows the double line of gravity conveyor that we finally decided would meet best the requirements of the cylinder-machine line. This conveyor extends the entire length of the line and is divided into three sections, each having a slight pitch to assist in propelling cylinders forward. The idea of dividing the conveyor into sections was to provide convenient passages through the line at these points and to maintain the required slope without making the delivery end of the conveyor

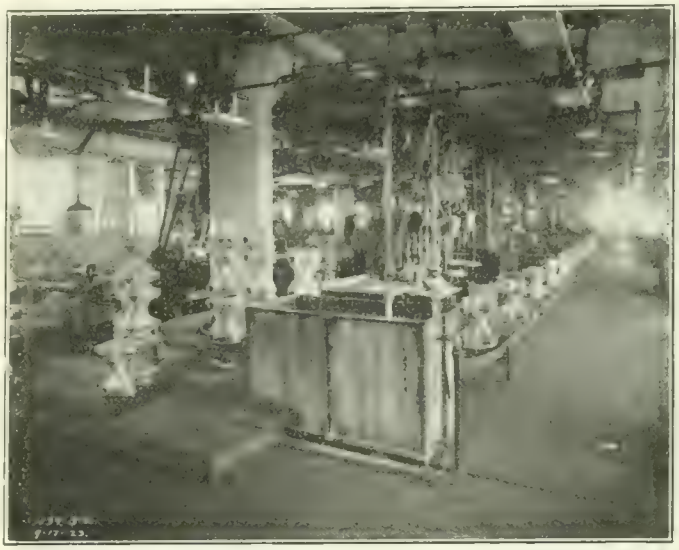


Fig. 6 Gravity Line for Rear Axle Gear Case

too low. This installation has been in operation about 6 months and is now operating perfectly. It is not necessary to store cylinder castings anywhere except on the conveyor, as a sufficient number of cylinders to meet the requirements of each machine operator are always on the conveyor, even though the machine at the preceding station may have been down for several minutes. This is an excellent illustration of the point I mentioned earlier with reference to our inability to move parts mechanically between machine operations that were not performed on the conveyor itself.

Still another section of conveyor, installed in the cylinder department, was intended originally to carry the finished cylinders from the inspection bench to the storeroom for finished cylinders on an adjacent floor. This was an overhead-cable type of elevator having the feeding and delivery ends for the attachment of the castings lowered to a point conveniently within reach of the operator and extending directly along the ceiling of the room for the remaining distance. Unfortunately we have no illustration of this conveyor, as it was removed shortly after it had been installed. The reasons for its failure to operate properly were that no storage space whatever could be provided for finished cylinders be-

Fig. 7 The Transmission Assembly Conveyor

cases, the end of the machine line and the stockroom, and that the last operation on the machine line could not be at the proper point to hang the cylinder castings as the carrier bodies passed that station; a third reason was that there was no attendant stationed at its delivery end all the time. Its failure to suit our conditions can best be summed up by saying that we were unable to synchronize the production of cylinders and the positions of these men closely enough, without requiring the services of each of the men for a longer time than would be required to move the cylinders manually between the points served. Shortly after attempting to put this conveyor into operation it was decided to dismantle it, and to move the cylinders by truck from the cylinder machine line to the stockroom. In summarizing the results obtained by the installation of cylinder-handling equipment, it may be well to state that we actually reduced the number of cylinder castings in process by 2000.

Gravity Conveyor for Transmission Cases

Another illustration of what can be done with a simple section of gravity conveyor is shown in Fig. 5. This is the machining line for the transmission case, and offers a good example of what must be accomplished in bal-

ancing operations in order to handle the part progressively; and by progressively I mean the advancing of the part directly from one operation to the next without maintaining a large supply of stock between the operations. Before installing the gravity line and arranging the machines in their proper sequence it was often necessary to have 700 to 800 transmission cases in process in order to assure a uniform production at the desired rate. Since the rearrangement of the machine line and the installation of the gravity conveyor we need not have more than 150 transmission cases in process to meet our maximum production requirements. A total of 35 operations on this transmission case are performed by 12 men, one man in some cases covering as many as 3 machines in order to take care of his share of the operations. This is probably one of the best illustrations that we have of the necessity for balancing machining ele-

Fig. 10—Main Line of Axle-Assembly Conveyor

ments in progressive manufacturing. Incidentally, the cost of machining transmission cases diminished 20 per cent with this installation.

The next illustration, Fig. 6, is similar to the one just explained on the transmission-case line. The rear-axle gearcase is carried through all the machining operations and is delivered to the starting end of the axle-assembling line. The most important point accomplished here was a very material reduction of the number of castings in process, as well as a considerable reduction in the cost of labor on account of the various operations being properly balanced. There are, of course, a large number of places throughout the plant where gravity conveyors are employed for the handling of parts between departments and between machines, but it is not necessary to discuss them in detail as they are similar to the examples already shown.

The next type of conveyor that enters into the discussion is the self-propelled type, on which all operations are performed on the conveyor. Fig. 7 shows a straight-

FIG. 11—FRONT-AXLE ASSEMBLY CONVEYOR

line power-driven chain conveyor for the assembling of transmissions. This conveyor, in its operation, resembles a long moving bench on which are carried a number of duplicate fixtures that will accommodate the transmissions in each of the assembly positions. The transmission case is placed in the assembly fixture at the far end of the conveyor and the various parts are assembled into it as it proceeds along the length of the conveyor frame until it reaches the delivery end, where it is taken off and sent to the engine-assembly department. The empty fixtures are returned underneath the conveyor, where they can be readily seen in the illustration. The design and installation of this conveyor did not present

FIG. 12—REAR-AXLE ASSEMBLY CONVEYOR

any particular difficulties except that the assembly fixture had to be made to fill a number of different requirements. How well the conveyor fulfills the conditions can best be indicated by the fact that after putting it into operation we found that we could produce our maximum schedule with 50 fewer transmissions in process and with 18 per cent less labor-cost than before.

It might be well to state at this point that we, at least, believe that one of the most important points to be gained by the use of conveyors of this type for assembling purposes is that the department foreman knows in advance exactly what his production will be at the end of the day, a fact of which he is most certainly ignorant when conveyors are not used.

The engine-assembly conveyor, shown in Fig. 8, consists of a U-shaped conveyor, on which the crankcase-assembly operations are performed on the right leg and the other operations on the left leg, the two legs traveling in opposite directions. Both conveyor lines are driven from a single drive-head so that there is no trouble in maintaining synchronism between the two lines. Some of the operations performed in assembling our engines require the use of an assembly jig in which the engines can be inverted, as is clearly shown in Fig. 8. These jigs are the result of several years of develop-

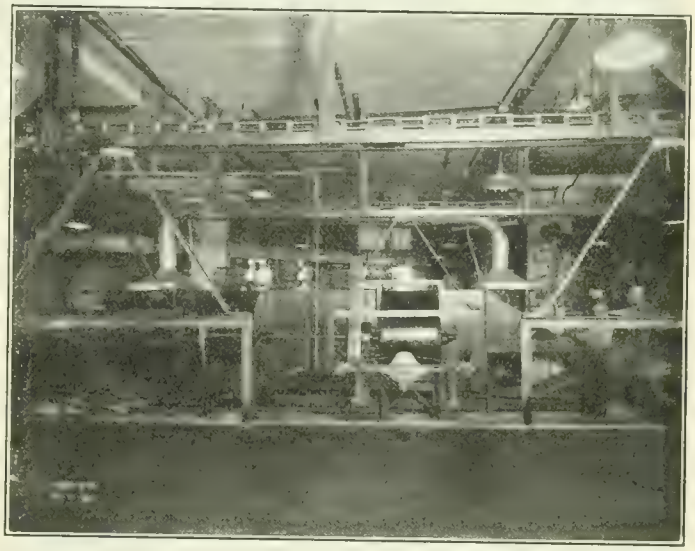


FIG. 13—AXLE WASHING AND LOADING END OF AXLE PAINT CONVEYOR

ment and were in use for some time before the conveyor line itself was installed. This conveyor is a good example of the simplicity of applying the conveyor idea to the average well equipped assembly unit. In our case it was necessary only to lay the channels and install the drag chain and driving end to complete the job. No difficulty whatever was experienced in putting the conveyor into operation, and the men along the line seemed to appre-

FIG. 14—SPRAY STATION ON AXLE PAINT CONVEYOR

[illegible]

[illegible] the fact that it was no longer necessary to drag the heavy trucks from station to station. Here again we were able to realize a reduction of 15 per cent in the labor cost of building engines.

When the assembled engine was delivered from the end of the assembly line it was our practice to use two movemen to transport it to the engine conveyor that runs parallel to the chassis-assembly line in an adjacent department. This resulted in a considerable strain on the trucks and very often in an accident, in which the engine would be upset, with the danger of serious injury to one of the movemen. Fig. 9 shows a simple monorail installation with an electric hoist, over which the engines are now moved, it being necessary to employ only one man and with entire safety to him.

Arrangement to Allow Proper Functioning

In considering the arrangement of our plant that was necessary to allow the conveyor equipment to function properly, we decided to make a new department for the manufacturing of all parts required for both front and rear axles. This department was located where the several assembling operations on both front and rear axles could be performed along opposite sides of a long single-

[illegible]

chain conveyor, shown in Fig. 10. This conveyor, by the way, is the only example of a power-driven conveyor that we have in our plant whose only function is the moving of the work between machine operations; and it may be well to state at this time that I still believe the statement, which I made earlier in the paper, that ordinary gravity means of sliding these parts along would have functioned as well as, if not better than, the power-driven conveyor. However, we have allowed this conveyor to remain because we did not have so much difficulty in synchronizing the operations. The axles are built on this conveyor only so far as is shown in the illustration. For the rest of the operations they are removed from the conveyor, the front axle on one side and the rear axle on the other, and carried by a small overhead trolley to a station at the starting end of what we call the final-axle-assembly conveyors. Fig. 11 shows a conveyor of this type on which the operations of assembling connecting-rods, steering-knuckles and the like are performed. This is a double-chain type of conveyor having heavy steel plates for cross-members, which are so made in order to resist the heavy hammering that is necessary in assembling the springs into the spring-clips and

Fig. 17—Second Level of Body Trim Line

aligning the springs before finally bolting them into place. The speed of this conveyor is synchronized with that of the conveyor shown in Fig. 10 so that there is no surplus of axles between the two. The completed axle is removed from the conveyor by the overhead hoist, shown in the foreground, and is fed directly into the washing machine, where it is washed preparatory to painting. The inspection operations of both the front and the rear axles are conducted directly on the ends of the assembly conveyors. Fig. 12 shows the rear-axle conveyor, upon which the final-assembly operations are performed. Here again the conveyor is made extremely heavy to withstand the heavy pounding necessary for the assembly operations. The axle in this case is moved lengthwise along the conveyor, instead of crosswise, for the operators' convenience in performing the assembly operations. This conveyor also delivers the axle directly to the overhead line that transports it to the washing machine, which can be seen at the extreme left of Fig. 12. Fig. 13 shows the washing machine through which the axles pass, as well as the feed and delivery ends of the axle paint conveyor. Axles are removed from the end of the washing machine by an electric hoist, and are

hung directly on the carriers of the conveyor. They are moved along this conveyor to the right, to the spray booth shown in Fig. 14, where they receive a heavy coat of paint, then through this spray booth to the end of the room and back in a parallel line on the other side of the post line. The arrangement of the axle-paint conveyor as a whole can best be seen in Fig. 15, which shows the axles returning from the end of the room after the paint has been applied to them. The axles are unloaded at this point and are transported by trucks directly to the chassis-assembly line, which is on the same floor as the axle-manufacturing unit. By concentrating the manufacture of axle parts and finished axles into one unit we avoid a large amount of stock-moving of very bulky parts that gave considerable trouble under the old method. We have obviated the principal excuse offered by the several foremen interested in the manufacture of axles and parts by putting the entire manufacturing unit in one location. There can be no excuse for the shortage of some part manufactured elsewhere in the plant, inasmuch as all parts are manufactured in this one room, and a more uniform production of axles is obtained. We experience no trouble in meeting the

Fig. 18—Floor Level of Body Trim Line

maximum production requirements and could build more axles if they were needed. We have reduced the actual number of axles in process by about 500, including fronts and rears, and aside from reducing the moving cost we have lowered the actual manufacturing cost of axles by 15 per cent. The operation of this conveyor leaves no doubt whatever in our minds as to the practicability of the unit system of manufacture, for a large portion of the parts involved, even in plants of the capacity of ours.

Handling the Trimming of Bodies

One of the most interesting installations recently made is a conveyor for handling the trimming of open bodies. Fig. 16 shows the first stage. The conveyor itself is divided into three stages, each located on a different level, the elevation of the body being fixed according to the needs of the operations being performed on it at that particular point. The first section is elevated 24 in. above the floor and brings the body to the proper height for such operations as installing the wiring back of the dash, putting in the buttons for side-curtains, and the like. You will notice that the conveyor line is free from crosswise obstructions so that the operator can work

Fig. 19—The Axle Loading Station

inside the body with his feet on the floor without danger. The body is loaded on the starting end of the conveyor with a small electric-hoist and travels the entire length of the conveyor line mounted on a low four-wheel truck, which can be seen in the illustration. On the second elevation, which is shown in Fig. 17, the body is brought down to a height of about 10 in. above the floor, for the convenience of the trimmers who must necessarily work over the rear end of the body and over the sides. A false floor was built around this conveyor line to bring the operator to the proper level in order to avoid cutting through the floor for the return chain. This idea was simply an expedient to avoid a complication of local conditions where the return chain would have had to pass over the top of one of the railroad tracks that enter the building on the floor below. The first and second sections of the body-trim conveyor are driven from a single unit through bevel gears, the shaft of which can be seen in the foreground of Fig. 17. Building the top directly on the body required that the body be carried as close to the floor as possible. The way in which this was accomplished is shown in Fig. 18. You will notice that the body truck travels in an open space between adjacent flights of slat conveyor so that there is actually no opening in

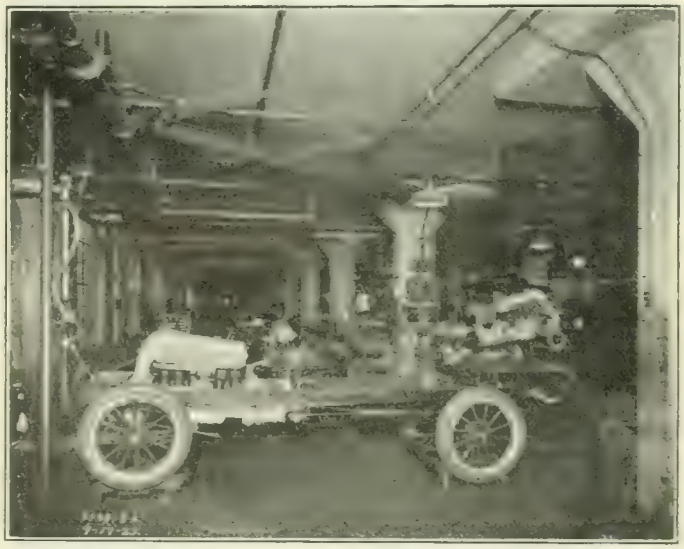


Fig. 20—Engine Loading Station

the floor at any point around the body, although the body is continually moving forward at the desired rate. It was necessary to build this type of moving floor to protect the top-builders who, of course, must work at all points around the body. The bodies, with the same trucks on which they traveled the length of the conveyor, travel by gravity around a curve, which is at the rear of this illustration, and feed into the openings between the intervals of slat conveyor. It is necessary, of course, at this point for the trimmers to guide the body so that it will be picked up properly by the driving edge of the

slat conveyor. This driving edge, which is protected by an angle iron leading, drives directly against one side of the body truck. In the foreground is shown the end of the top-building line where the body is delivered complete ready for loading on the chassis. The method of lifting the body truck over the openings in the channel track through which the slat conveyor passes is shown quite clearly by the two strips on either side of the opening. The thrust of the driving edge of the conveyor pushes the body truck over these two strips and allows the casters to bridge the gap in this way. From this point they are pushed to the loading deck which is directly adjacent to this point.

The chassis and final-car conveyors are the largest that we have, and have been in operation the longest. The chassis conveyor, as it is now operated, is in the form of an L. The starting end of the line is shown in Fig. 19. At this point the sill assembly is mounted on the chassis truck and the axles are fitted. Fig. 20 shows the corner of the L, the point at which the engine is mounted. From this point forward the chassis travels in a straight line to the point where the body is loaded. Fig. 21 is a view of the chassis line taken from the end opposite to that of Fig. 20, that is, looking toward the point where the engine is loaded, and shows in the foreground a chassis that is ready to enter the body-loading station. The trucks on which it has traveled up

Fig. 21—Starting End of Finished Car Line

to this time are at present removed by the inclined channels shown, but this arrangement is only temporary, and we plan to keep the chassis on the truck until after the body has been loaded and the car is ready for delivery to the final-car line. The original chassis-layout was somewhat different from the present L-shaped arrangement on account of the larger number of operations

Fig. 24—Delivery End of Finished Car Line

that were necessary when this installation was first made. A very good idea of the relative locations of the chassis, engine and final-car lines may be obtained from Fig. 21. The chassis line is traveling in the opposite direction to that of the other two lines. Fig. 22 is a view of the one section of the old chassis-line that has since been removed, the change in layout resulting in the shortening of the travel of the chassis during building by several hundred feet, and in reducing considerably the number of chassis in process, while at the same time making available about 5000 or 6000 sq. ft. of additional manufacturing space.

The Final-Car Line

From the end of the chassis line, after the body has been loaded, the car is moved by a small transfer-car directly to the entering end of the final-car line, shown in Fig. 23. This photograph also shows the relative location of the engine-conveyor line, which supplies engines to the proper point along the chassis line. The final-car and engine conveyors are both of the belt type, the cars progressing on the belt without their wheels revolving. This type of conveyor was originally chosen to allow certain drilling operations to be performed through the spokes of the wheels, and has given remarkably little trouble considering the extremely heavy load that it carries. Although it has been difficult at times to maintain a uniform rate of speed on this conveyor on account of variations in the tension of so long a belt occasioned by changes in weather conditions. Fig. 24 shows the delivery end of the final-car and engine lines. Much might be said with reference to the advantages of using conveyors for chassis and final-assembly work, but I believe we all appreciate just what it means to any manufacturer who installs a conveyor system, in eliminating the delays occasioned by stock shortages, inability to keep the floor well arranged and the impossibility of predicting exactly the rate of production that can be obtained from the department. In our case the conveyor equipment has paid large dividends, and since its installation we have operated with nearly 40 per cent less labor-cost than before.

Practically all the conveyor illustrations shown have been installed within the last year, with the exception of the chassis and final-car conveyor-lines. We are absolutely "sold" on the idea that conveyors can be made to pay dividends even with a production such as ours, and

Fig. 25.—A New Line for Final Inspection of Cars Just Being Installed

are still making careful studies of other departments with the idea of installing additional conveyor equipment of some sort.

We are making one extensive installation at this time, which is not yet ready for operation, for handling the finished cars through the final-inspection and touch-up operations. The present condition of this conveyor is shown in Fig. 25. It is simply a drag-chain conveyor about 360 ft. long, which will be provided with the necessary stations throughout its length for handling the operations required.

I simply mention this in passing, in order to impress upon you the idea that although our experience with conveyor equipment has been short, we are convinced beyond a doubt that it pays and pays well.

ACCIDENT PREVENTION

THE day has gone by when safety work was considered an humanitarian fad; the experience of employers who have undertaken it along rational lines proves too plainly that it is good business. Gone by, too, is the day when its economic value was measured solely in terms of damages or compensation saved, or lessened insurance cost. Considerable as the direct costs of accident may be they are much more expensive to an employer through the lost time of the injured men, through the interruption of the work of others caused by accidents, through the waste of material and the spoiling of product by new men, through their lessened production and through the time of foremen or others diverted for their training. All such interferences with the ordinary course of a plant's work cause a loss in efficiency that is distinctly measurable in dollars and cents. And the overhead expenses are running along just the same, but without the same degree of offset as had the accidents not occurred.

Not only does safety work cut down the loss in efficiency due to accidents but it tends to increase output. The less time a workman has to devote to avoiding injury, the more he has to give to production. And the spirit of cooperation among workmen developed by organized efforts is also plainly reflected in a greater interest in their work.

Another costly feature of accidents is found in the part that they play in labor turnover, that apt expression for the opposite of a stable working force. Every employer knows how expensive this turnover is; how important it is to the general efficiency of his plant to keep his labor force as intact as possible. The influence of safety work on labor turnover through lessening the number of employes injured and through promoting better relations between employer and employed is especially needed at this time when labor conditions still react, even at this late date, to the disturbing effects of the war.

When we stop to consider these varied ways in which the prevention of accidents is of importance to industry, we cannot fail to appreciate the real value of accident prevention in industry and feel a responsibility for seeing that an efficient safety organization is producing results in our plants.—David Van Schaak in *American Industries*.

The Human Element in Production

By W. F. Jameson

Production Meeting Paper

PRODUCTION is largely dependent on the human element, which is called by different terms according to the degree of intelligence expected from persons of different ranks; varying from ordinary stupidity among those of low intelligence to the "errors of judgment" of those higher up, it has been defined as a "temporary lack of application of one's attention to the thing at hand," and its effect on workmen of various temperaments is to lower production. Concentration is shown to be the central truth and the cause of one man's superiority to another. When supplied with an incentive, such as that of feeling that he is working for himself, a workman will concentrate his attention on his work with profit both to himself and to his employer. But apparently insignificant things preying on the mind will often cause a lack of concentration. Education is an endless process of growth and accomplishment. The motive back of the desire for a college education is the gathering of a fund of knowledge and experience that will enable one to cope better with the problems of life. A going manufacturing company offers real problems for solution and obstacles to be overcome. Every job can be made a training school of experience if the holder will make it so; the production game furnishes everything necessary for growth. Inertia is the great obstacle, while autosuggestion, on the other hand, is of great assistance in instilling spirit into one's work. The determination continually to learn something new, to overcome all obstacles and to take advantage of opportunities that are presented will not only make the time pass quickly but will also increase efficiency.

THE human element has always been and necessarily always will be a most vital factor in every undertaking that marks the progress of civilization. Production is one thing that surely has an influence on the world's progress. We need offer no apology, then, for considering the human element in its relation to production in general and, more specifically, to the high-powered production of the automotive industry. But before we consider this subject let us at first make sure that we have a common understanding as to what is meant by the expression "human element." By reference to the correspondence files of any concern that purchases fabricated material from outside sources, you will find the term used with reckless freedom, with the apparent belief that it is a complete and satisfactory alibi in every instance in which the product does not measure up to standard quality.

The expression at times is also considered somewhat synonymous with a lower grade or less intelligent class of humanity. This is a mistake, as its influence is felt from the lowest ranks to the highest. We use such terms as "error of judgment" when thinking of the semi-executive man, and when we get into the executive class proper such things are to be expected, if we accept Elbert Hubbard's definition of an executive as "one who makes quick decisions and is sometimes right."

Tracing back the more common interpretation of the meaning of the term "human element," we find it to be a *temporary lack of application of one's attention to the thing at hand;* and the attitude of one's mind is the controlling feature that directs one's attention to the thing at hand. Far too little consideration has been given to this subject in the case of the ordinary workman while he is on the job, yet much depends on just that. We have overlooked the possibilities of training the mind behind the man; much as man overlooks nature in her majestic moods. We see the sun rise and the lightning flash, and hear the thunder roll, but we are blind and deaf so far as being impressed by such wonders is concerned. Our sensibilities become calloused toward an oft-repeated occurrence. We have thought of workmen as so many hired hands for so long that we have thought ourselves into expecting no more than their hands; and in too many instances they reciprocate. We have made motion studies of hands and have accomplished wonderful results from a production standpoint, but are there not still greater results to be obtained by cultivating more than the machine side of the man?

It is fully granted that there are a host of workmen who, from observation, show no tendency or inclination to exhibit any more than a machine side, and much credit is due those systems which utilize this phase of human energy in bringing about a high state of efficiency in production; but considerable additional cost goes hand-in-hand with such methods of production, an instance of which may be cited in the fact that, in order to guard against a possibly defective piece's entering a sub or main assembly, the items composing that assembly must have 100 per cent inspection; and many inspection operations require more than the machine side of a man. Estimate, then, the cost of inspection in an automobile plant, taking into consideration the fact that numerous items can be handled and placed in assemblies in less time than it would take to handle a single item for inspection. The number of inspectors required would be practically equivalent to the number of employes in the production force.

Importance of Right Thinking

We find, however, that the majority of workmen are capable of thinking, and that fact in itself lends encouragement to the proposition of coaching them to think rightly. Furthermore, it is surprising how readily men will respond to treatment of this nature. We cannot deny that a man who takes an interest in his job and applies himself to it will turn out better work with fewer mistakes and a larger output. There are plenty of good men who take an interest in their work when they apply themselves to it, but the difficulty lies in getting them to apply themselves consistently; yet it is not so difficult after all if the proper methods are used. We can hardly fail to recognize that civilization is fast drifting into a new epoch of thinking. Many teachers

Chief engineer, Cleveland Automobile Co., Cleveland.

are spreading various gospels among the people. The Hindoo, with his "Peace, Peace, Peace," is taking hold of the minds of many, but when we strip these various movements and teachings of their commercializing cloaks, we find that one central truth, though perhaps expressed in different terms, lies at the heart of all. In fact, this central truth can be expressed in one word, *Concentration.* Though, at first thought, there may seem to be little connection between concentration and the human element in production, let us see if we cannot prove the following assumptive facts to be not only real facts, but sound working principles that can be proved in actual practice.

(1) Every man has a great storehouse of latent power and energy, the key to the door of which is concentration

(2) When a man begins to draw on the storehouse of energy that he possesses, his work and efforts stand out above his fellow-workman's in remarkable contrast

(3) It is possible to teach any man how to use the key of concentration, but he is not likely to use it unless he has an incentive to do so

(4) Of all incentives the most productive and most lasting is the feeling that one is working for himself

(5) It is possible for a man to become saturated with the thought that he is working for himself while on the payroll of his employer, with profit to both as the result

(6) It is easy to sell men to the foregoing principles but to keep them sold requires repeated efforts on the part of the salesman who himself must first be permanently sold

(7) In the production field under present conditions the foremen are the logical salesmen, and they themselves should keep each other permanently sold by get-together meetings for this special purpose

In order to grasp fully the import of the first assertion, we must digress for the moment from things mechanical, and border on the realm of what some might term religion, while others would term it universal law. Terminology means little, as is illustrated in a verse or two from Dr. Carruth's poem, entitled "Each in His Own Tongue:"

A fire-mist and a planet,
A crystal and a cell,
A jelly-fish and a saurian,
And caves where cavemen dwell;
Then a sense of law and beauty
And a face turned from the clod—
Some call it Evolution,
And others call it God.

A picket frozen on duty,
A mother starved for her brood;
Socrates drinking the hemlock,
And Jesus stretched on the rood;
And millions who, humble and nameless,
The straight hard pathway trod:
Some call it Concentration,
And others call it God.

Development of Well Balanced Brain

Science teaches us that there are 43 distinct brain areas or faculties. These centers can be developed into an active state or they may be left dormant. The greater the number of brain areas we live in and the more evenly balanced their capacity, the more capable we are, but, as a matter of fact, there is not a perfectly sane man on the face of the earth. We are all lop-sided in some of our faculties. Concentration, then, is the directing of the blood to the various brain centers at will and the shutting out completely of everything else, except the thing we wish to center our attention on. If it were easy to do this to a marked degree we can hardly estimate the power and force that would be at our command. We could tap the reservoirs of universal knowledge through our subconscious minds. But this must remain a dream at our present stage of development, though a dream not incapable of realization in a not far distant generation.

Let us return to earth then and see what even the first steps in this direction will do for the shop workman. Here is a man at a bench, with nothing particular on his mind. His hands have moved in certain directions often enough to have acquired a habit to some extent. His mind is like a sensitized camera-plate, subject to impressions from any angle. Thoughts fly in and out of his mind at random, any one of which may remain just long enough to create a mood, which is nothing more than an impression taking a permanent set for the time being; and we know what moods will do and how they are reflected in one's work. Perhaps some word of profanity from a nearby fellow workman fell on his ear early in the morning, but it was enough for a slight impression of dissatisfaction to gain weight, and in a short time everything is "all wrong" and that feeling of "to hell with this job" shows up in his work.

Such uncontrolled thinking and misdirected energy are the unknown quantities of the day's production, because of which poor workmanship occurs and for which the human element gets the blame. But next to this workman is one that, by conscious or unconscious training, has learned not to register unwelcome impressions. A deaf ear is turned on expressions that he knows by experience would change a constructive into a destructive mood. He selects the thoughts that he allows his mind to dwell on. The day's output from such a man can be banked on, both as to quality and quantity. The boss points him out as a good man. His name is mentioned frequently when reliable men are wanted for certain operations. Perhaps a more responsible position opens up; again his name is mentioned and he gets an opportunity to advance. This is every-day experience and takes place in any average plant; and it is readily seen that the one mark of distinction between the two workmen cited is the fact that the first makes no attempt whatever to select the thoughts that he allows to occupy his mind, while the second concentrates to the extent that worthless impressions or thoughts are purposely barred from registering on his brain. If just this amount of attention paid to the matter of concentrating one's mind on the thing at hand will produce the results mentioned, then the more remarkable results from further efforts expended can be little questioned, and more and more the second item mentioned above will come into prominence in that the work turned out and the results accomplished by the man's using this method will stand out in remarkable contrast to the output of one who drifts along from day to day, easily impressed by every passing influence, without the stabilizing effect that is produced by an active faculty of concentration. Watch any man work whose mind is on any what-not subject foreign to his work and no further evidence will be needed to convince one of the truth of these facts.

The third point in the hypothesis is the necessity for an incentive to acquire the habit of concentrating. There is scarcely a thing we do without having a motive behind

the boards with the introduction of new production methods; hence the necessity for a workable substitute; and that substitute is our fifth point. Let us repeat it: It is possible for a man to become saturated with the thought that he is working for himself while on the payroll of his employer, with profit to both as the result.

The true motive back of a man's desire for a college education is the gathering of a fund of knowledge and experience that will enable him to cope better with the problems and obstacles of the future, with the hope that such training will pay him larger cash returns when he sets out to make a mark for himself. He spends several valuable years of time and good money for this training. The stage setting in college is necessarily artificial. It reproduces as closely as possible conditions in the outside world and teaches the student how to act under these conditions. The student goes through this period of training, graduates with honors, and goes out to sell himself to the world. Not only does he meet obstacles and problems that were not reproduced in college, but he sees a vast difference between the real conditions of business and their reproductions in college; quoting Elbert Hubbard again: "A man can spend four years in college and succeed in spite of it." That would seem quite severe if we were not familiar with Hubbard's style. We do know, however, that success depends entirely on the man. A college training amounts to nothing in some men, while to others it means everything.

Now let us look at another institution located, perhaps, next door to the college institution. It is a going manufacturing concern. There is no make-believe in its set-up. Real conditions exist, actual problems present themselves for solving, numerous obstacles must be overcome. Our first thought is: What a wonderful opportunity for training; and that is just the point; it is. Every job can be made a training school of experience if we will make it so. Every problem we face and master fits us better to meet the next obstacle just as the young oak tree grows stronger with each storm it weathers; otherwise it would never become the mighty oak. Hazards improve one's game of golf. When our efforts are taxed in the accomplishment of any undertaking, we can accomplish the same task a little easier the next time and are prepared for still greater tasks. The more we do the more we can do. It is an endless process of growth and accomplishment. That is the kind of training course industry offers to anyone who accepts it in this light; that is the point we must put over to the workman. Everything necessary for our growth is furnished in the production game, opportunities to solve problems and overcome obstacles that we could not go out and create single-handed; and we absolutely must fight battles if we would win victories. Think, then, of the opportunity every workman has when he is offered such a training course and, instead of having to pay tuition, he is actually paid real money for attending a real school of real opportunities.

Value of Auto-Suggestion

Try to conceive, if possible, a group of workmen passing the time-clock and every click of the clock releasing in each of their minds the following auto-suggestion: "I am going to work for myself today by learning something new about my work. Bill Jones has a harder job than I have and I am going to find out what he knows that I do not; you can take it from me that from now on nothing gets by me. I am going to make myself capable of handling the hardest job in this shop and handling

it better than it ever has been handled. I am going to start my school days over again right here in this plant." What do you suppose would happen if a group of men got a spirit like that instilled into them? Time flies when one is working with such an incentive, and there is a wonderful sense of happiness in one's work when there is a feeling that time is all too short to accomplish what one has in mind. After all, education and experience are about the biggest assets of life, and education is nothing more than the sum total of sense impressions made on the brain. To realize this and take advantage of every opportunity for enhancing our education is surely working for one's own interests, and there is no job that does not offer such an opportunity. We hear a great deal about loyalty to the firm for which we are working, but that is putting the cart before the horse. If one imbibes the thought that one is working for one's own interests and considers one's own development primarily, the company's interests, though considered as secondary, are taken care of with constantly increasing efficiency. The two are inseparable, each depending on the other.

These principles are not new. We simply have not taken advantage of them to the extent that we could and should have. They have been and are being applied here and there to a limited extent either consciously or unconsciously, and you can measure their results every time. As an example of this, a department head came into the office while some of these thoughts were being dictated. He left the office without stating his reason for calling, but returned later to say that his first visit had been to request help on a certain problem but, hearing about the advantages of hunting for problems to solve and obstacles to overcome, he had decided to go out and lick the proposition himself; he returned only to state that it had "worked like a charm." Surely, it will work. It is the working out of the natural law of cause and effect, but there is another force which seems to work in opposition, that we shall put in question form: Why is it easier to form bad habits than good habits? Perhaps it is that there are so many more bad habits than good ones. On the same basis of reasoning, perhaps that explains why so much work finds its way to the scrap-heap, there being only one right way to turn out a job compared with a hundred or more wrong ways.

Concentrating on the fact that one's job is a school of unlimited possibilities is a mighty fine habit, productive of untold good, but, regardless of that fact, if that attitude of mind slips away from us, it may remain absent for a long time, or until some person or incident reminds us of what we are missing. Hence the occasion for the last two statements in the outline submitted, namely: The foreman should train himself to control the attitude of mind of his men while he himself is prevented from dropping back into ruts by "constant reminder" conferences with other foremen.

Once more let us quote Elbert Hubbard, who incidentally was a great exponent of the doctrine of finding joy in one's work. He believed in certain principles of socialism, but stated that they must be brought about by evolution, instead of revolution. This is likewise applicable to the principles herein set forth. It takes good salesmanship to "put across" any idea to a group of men of various types and temperaments, and in this case it should not be attempted, collectively at least, until the group has been 100 per cent "sold," individually, which of course is a big stake to hope for. The idea has been worked out successfully to a marked degree by the foreman's explanation to his "key-men," who in turn act the principles instead of preaching them, until development is noticed and opportunities present themselves for more intensive efforts in salesmanship.

There has been no attempt in this paper to give an exhaustive treatise on the human element, as the subject is much too broad for even one phase of it to be covered completely in this manner, but the aim has been only to outline a few points, with the hope that thought may be stimulated toward the possibilities of utilizing more of a man than is usually exhibited on the surface while he is on the job. In the undercurrent of a man's thoughts are emotions which, if aroused, will release energy tenfold greater than that usually exhibited. To bring this additional capacity to the point of expression requires an awakening on his part to the personal gain to be derived from doing so. Personal contact is productive of results in bringing this about, and opportunity lies at the feet of the foreman, with his keymen as part of the scheme for accomplishing it.

APPLICATION OF RESEARCH

OF course, intuition has its value and, when guided by adequate knowledge, constitutes the distinction between a class A and a class B mind. "We are poets" was the claim made at a mathematical congress many years ago, and it is the artistic faculty of recognizing and selecting among almost innumerable data those of prime significance that constitutes the distinction between the scientific thinker and the mere "researcher" who does the hodman's work of recording observations and measurements. Indeed, some of those who have made really serious contributions to the advance of scientific thought have not themselves been anything exceptional as either observers or experimentalists, and the converse also holds. Many instances could be adduced in support of this contention, and it is in fact generally recognized that many more men are fitted to contribute to scientific data than to advance scientific thought.

The great engineer and the great organizer must also be gifted with intuition. It is they who have to bridge the gap between a laboratory experiment and its practical applications. The gulf between the two is vast and, to free it, other qualities than mere mental acuteness are demanded, of which perhaps the most conspicuous is courage. Pepys tells in his Diary of some acquaintance who ventured and lost £20,000 in trying to improve methods of coal winning, and, to come to more modern times, more than one fortune was lost in practicalizing the ammonia-soda process before success was finally attained. This instance is in itself sufficient to show the lack of foundation for the statement of a well-known Oxford professor to the effect that a chemist might write on a half sheet of note-paper a formula that would keep a whole community in affluence. Neither carbonate of soda nor sulphuric acid can, however, be produced by a mere paper formula, any more than a steam turbine can be constructed by hitching a table of the properties of steam to a prime-motion shaft. Both the formula and the table may be of great potential value, but actually to realize this, much has to be risked and, in general, much lost before final success is achieved.—*Engineering.*

Factors Governing "Out-of-Roundness" Measurement

By A. H. Frauenthal[1]

Production Meeting Paper *Illustrated with* Drawings

It is stated that an out-of-round surface having an even number of high-spots requires a checking instrument that has opposed measuring points; and that, if the number of high-spots on the surface is uneven, an instrument having three-point contact, and one of the points of contact located on the center line between the other two, is necessary. Concerning the use of the three-point method, for close work, the angle between the three points of contact must be selected according to the number of high-spots.

Divisions of the subject include types of out-of-roundness and those peculiar to certain machines, the three-point measuring system, errors of the V-block method, use of the V-block for elliptical objects, other methods of checking elliptical forms and indicator-reading correction. Three items for instrument improvement are suggested to manufacturers.

ACCURATE measurement of "out-of-roundness" is an important item of inspection that, it seems, has not received due consideration even in our larger plants which use the most modern of measuring instruments. It is an item that affects quantity, quality and cost of production. If, through a fallacy of inspection methods, parts are produced and accepted for production that exceed the specified limits, there is generally a falling-off of production due to the difficulty of assembling parts in this condition, and the quality certainly is lowered through the loss of bearing area. On the other hand, if parts that are actually within the specified limits are rejected and scrapped, the decrease in quantity of production and the increase in cost of production are obvious.

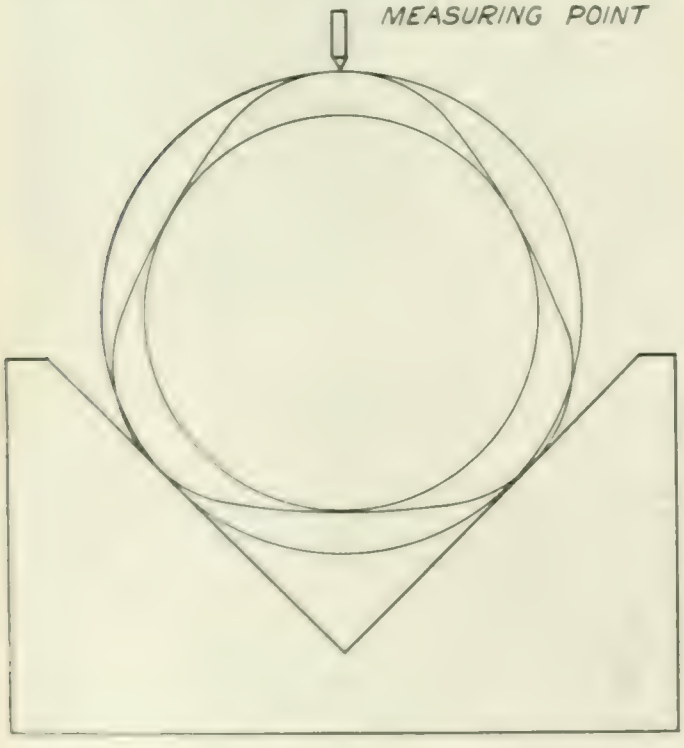
Types of Out-of-Roundness

The two different general types of out-of-roundness are "regular" and "irregular."

The irregular class comprises those objects which assume an irregular shape and, consequently, will not be governed by any set rules for their inspection. Under this head are parts that become out-of-round due to distortion in heat-treatment, crowding of tools by hard spots, and the like.

The regular class is composed of those objects the high and the low-spots of which manifest some mathematical continuity. Since the objects do contain high-spots and low-spots, their sections are no longer circles and must not be treated as such. If the object contains two diametrically opposite high-spots and two diametrically opposite low-spots, its section is an ellipse; and, if it contains a greater number of high-spots and low-spots and we consider the low-spots as sides and the high-spots as vertices, the section becomes either a triangle, a square or some other polygon. The paper deals with this latter class of out-of-roundness.

Automobile parts, such as piston-pins, small shafts,



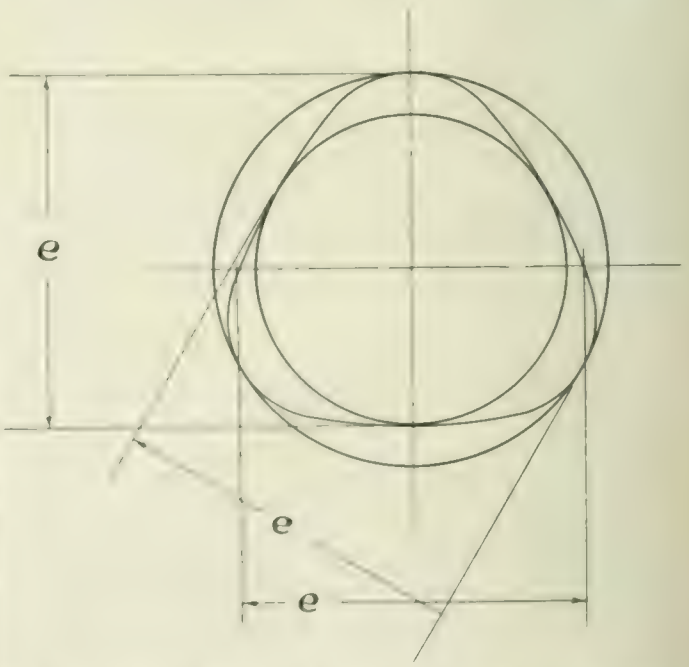


Fig. 1—Illustrating Sections of a Cylindrical Object, the Out-of-Roundness of Which Is Greatly Exaggerated

[1] Chief Inspector, Chandler Motor Car Co., Cleveland.

valve-lifters, shackle-bolts, roller-bearing pins and many other similar parts, are generally ground on centerless grinders. It has been determined that, on work that comes out-of-round from a centerless grinder, that the quality of high-spots and low-spots is always a number that is a multiple of 3. This condition is, no doubt, due to the fact that the centerless grinder has three points of pressure on the part being ground; namely, the grinding wheel, the feed wheel and the work support. On the other hand the number of high-spots and low-spots on work that comes out-of-round from the ordinary grinder employing centers generally is a multiple of 2. This is doubtless due to the two points of pressure on the piece being ground; namely, the centers and the grinding wheel.

Other machines also produce out-of-round work, particularly gear-driven machinery on which the number of high-spots or low-spots is equal to a multiple or factor of the number of teeth in one of the gears or the train of gears. Due to the varied shapes which an out-of-round piece may take, it is necessary to use different types of checking apparatus to determine the true conditions of each differently shaped piece.

The Three-Point Measuring-System

Fig. 1 shows a cylindrical object the out-of-roundness of which is greatly exaggerated. This is shown in the shape of a triangle and is the empirical form in which out-of-roundness manifests itself from the centerless grinder. It can be seen readily that if a checking method employing directly opposed measuring points were used on a piece of this shape, it might appear absolutely round; whereas, it actually could be considerably out-of-round. This is due to the fact that one of the measuring points would be located on a low point, while the one directly opposite it would be located on a high point, and this condition would persist while the entire periphery of the object was revolved through the measuring points. Since the actual amount of out-of-roundness of any piece is the difference in the diameters of the inscribed and circumscribed circles, it is necessary to use a measuring apparatus that registers in three places in the case of triangular objects.

Various three-point measuring-tools are on the market and, since their application and results are all approximately the same, we may use for an example the V-block method as employed with any of the numerous amplifying gages, such as the one shown in Fig. 2. The amplifying gage is merely an apparatus that employs a lever

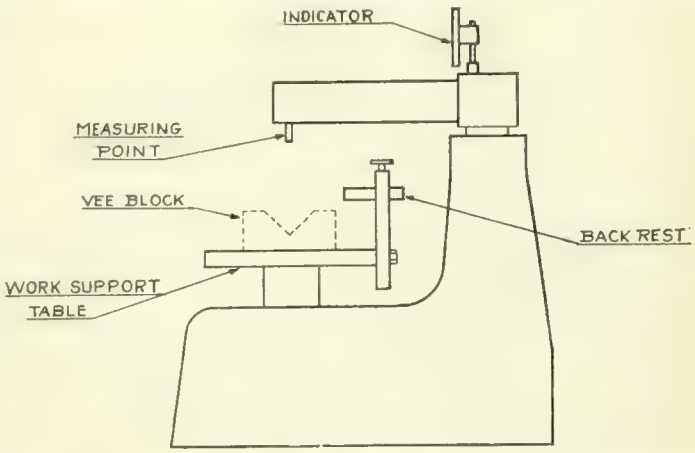


Fig. 2—Amplifying Gage Used with the V-Block To Measure Out-of-Roundness

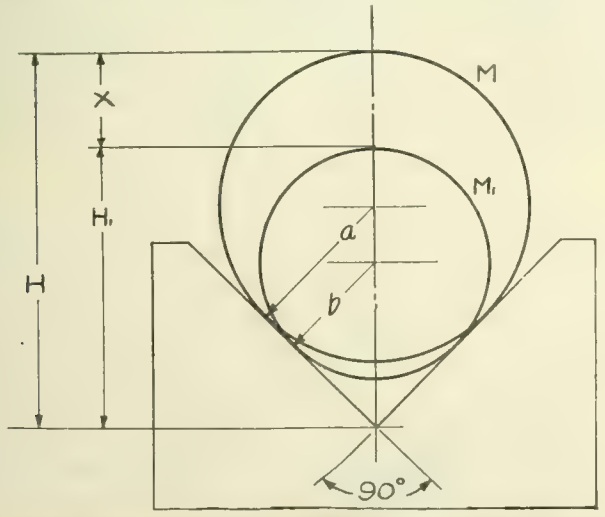
system to increase the movement of a measuring point held in contact with the work, and an indicator to measure the increased movement. While there are various different gages on the market, the principle of all is the same and with most of them are furnished different types of work supports, such as centers, V-blocks or flat plates.

Errors of the V-Block Method

To the casual observer, this method may appear to give accurate results but such is actually not the case and, for each different included angle of the V, a different correction must be applied to the indicator reading. This correction is obtained by very simple mathematics and we will demonstrate the necessary correction on a V-block having a 90-deg. included-angle, since this is the angle universally accepted for commercial V-blocks.

It would be incorrect to use a 90-deg.-angle V-block for a piece containing three high-spots, since the high-spots would be indexed 120 deg. from each other, thus requiring a V-block having a 120-deg. included-angle. This is merely an empirical example of how the correction is obtained; it is, therefore, permissible, and the correction obtained can be used when inspecting diametrical variations on parts within the tolerance for out-of-roundness.

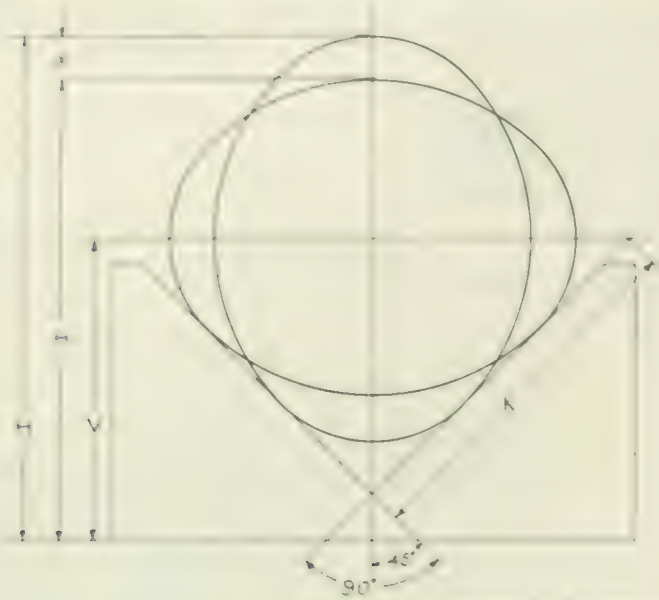
Inasmuch as the V-block method will, at some time or other, while the piece is being revolved, present the inscribed circle to the three registering points and, at some other time, present the circumscribed circle to the three



$D = 2a$
$D_1 = 2b$
$H = a + \sqrt{2a^2}$
$H_1 = b + \sqrt{2b^2}$
$X = (a + \sqrt{2a^2}) - (b + \sqrt{2b^2})$
$2X = (D + \sqrt{2D^2}) - (D_1 + \sqrt{2D_1^2})$
$X = 1.2071\,(D - D_1)$

DIFFERENCE IN READINGS AT M AND M_1 WILL BE 1.2071 TIMES ACTUAL DIFFERENCE IN DIAMETERS, I.E. THERE WILL BE AN EXAGGERATION OF APPROXIMATLY 21%.

Fig. 3—Drawings Showing the Errors of the V-Block Method and the Method of Working Out the Correction



a = MAJOR RADIUS
b = MINOR RADIUS
m = SLOPE
LINE $y = mx + K$ IS TANGENT IF $K = \pm\sqrt{a^2m^2 + b^2}$
LINE IS TANGENT AND $m = +1$ HENCE $K = \pm\sqrt{a^2 + b^2}$
$V = \cos 45^\circ \sqrt{a^2 + b^2} = .70711\sqrt{a^2 + b^2}$
$H = V + a$
$H = V + b$
$X = H + H$
$X = (.70711\sqrt{a^2 + b^2} + a) - (.70711\sqrt{a^2 + b^2} + b)$
$X = a - b$ WHICH IS INDICATED AMOUNT OUT OF ROUND. ACTUAL AMOUNT OUT OF ROUND = $2a - 2b = 2(a - b)$. THERE WILL BE A MINIMIZATION OF 50% IN AMOUNT OUT OF ROUND.

Fig. 4—Checking an Elliptical Object with a V-Block

engineering parts, we can use any two circles of selected diameters and find out how much higher one will set in the V-block than the other. This figure, minus the actual difference in diameters, is the amount of the correction. Fig. 3 shows the conditions with the correction worked-out; it is approximately 21 per cent.

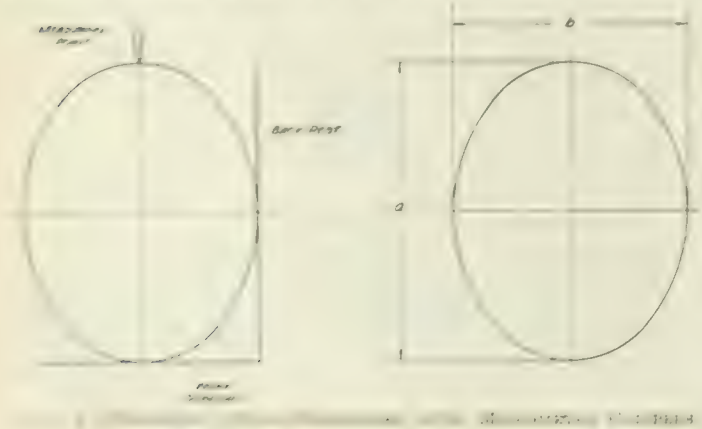
Elliptical Objects in a V-Block

The V-block method already described often is used erroneously on work for which the character of out-of-roundness has not been determined previously. The results gained from using this method with elliptical objects are shown in Fig. 4.

With reference to Fig. 4, we would be unable to register on the major or the minor peripheries and, as the major axis while in the lowest position would coincide with the minor axis, while in the highest position, the indicated amount of out-of-roundness would be the difference in the major and the minor radii. Since the actual amount of out-of-roundness equals the difference in the major and the minor diameters, the error is 50 per cent.

Other Methods for Checking Elliptical Forms

Fig. 5 shows a cylinder with the out-of-roundness in the elliptical form and exaggerated greatly. Inasmuch as the amount of out-of-roundness of any object is the difference in the diameters of the inscribed and circumscribed circles it would be a very easy matter to measure



this difference on the part shown merely by applying some measuring instrument with opposed measuring points, such as the micrometer caliper, to the distances a and b.

However, the micrometer caliper is no longer used for quantity inspection of work of this type, and has been replaced by the amplifying gage. The reasons for this are familiar to all, or are very obvious at least, and do not require discussion here.

In a manner analogous to that of the micrometer, the piece could be moved back and forth, horizontally, under the measuring point, until the highest and the lowest readings were obtained. This is a very accurate method, but is, unfortunately, slow. To overcome the difficulty of finding the highest and the lowest points and to eliminate the horizontal motion, which requires considerable time, the back-rest has been added as shown. When using this appliance, the original indicator-setting is made by a pluggage or master-piece which is moved back and forth under the measuring point until the highest reading is obtained.

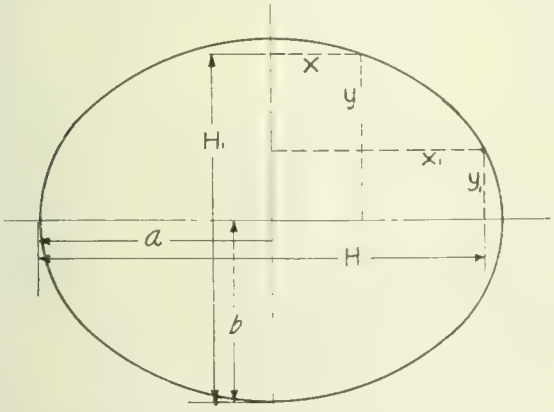
The position of highest reading is, of course, at the diameter of the circle and, with this obtained, the back-rest is moved-up to the master-piece and fastened in place. In the actual inspection, the piece being tested is held firmly against the back-rest and revolved under the measuring point. This method is very rapid; however, it adds a third measuring-point to the combination and hence requires analysis to determine whether the indicator readings require correction.

Indicator-Reading Correction

To determine this, let us first assume that the amplifying gage is in perfect condition as received from the manufacturer; that is, with the back-rest and the work-support perfectly flat and the measuring point rounded to give point contact and to permit the specimens to slide under the point readily. The elliptical piece is revolved as has been described and, when the lowest indicator-reading is obtained, the major diameter of the ellipse naturally will be horizontal, with one extremity against the back-rest, as shown in Fig. 6. This condition, of course, brings the measuring point off the center and the reading obtained is smaller than the actual minor-diameter. The amount that it is smaller depends

on two quantities, the actual amount of out-of-roundness, which is unknown, and the degree of curvature of the measuring point.

When the highest indicator-reading is obtained, the conditions are just the same in effect, a smaller reading than the major diameter is obtained, and the amount that it is smaller depends on the same conditions. Although, with a perfect ellipse, the measuring point is the same amount off-center when taking the highest reading as it is when taking the lowest reading, the difference in readings, which is the indicated amount of out-of-roundness, is not exactly the actual amount of out-of-roundness, even though we were able to procure point contact at the measuring point, which would eliminate the complication of the radius. It is, however, so nearly the correct amount that the method would be perfectly safe to use, even on so close a job as piston-pins, if it were possible to obtain the perfect conditions just described. However, it must be remembered that all readings, whether used in checking roundness or size variations, will be complicated by the radius on the measuring point. To overcome this condition, trials should be made periodically with known-diameter master-pieces to obtain corrections for radius and wear of the measuring-point radius.



a = MAJOR RADIUS

b = MINOR RADIUS

$\therefore \frac{a-b}{2}$ = AMOUNT MEASURING POINT IS OFF CENTER

$\frac{X^2}{a^2}+\frac{y^2}{b^2}=1$ (EQUATION OF ELLIPSE)

$X=\frac{a-b}{2}$

$y=\frac{\pm b}{2a}\sqrt{3a^2+2ab-b^2}$

$H_1 = b+y$

$H_1 = b+\frac{b}{2a}\sqrt{3a^2+2ab-b^2}$

$\frac{X_1^2}{a^2}+\frac{y_1^2}{b^2}=1$ EQUATION OF ELLIPSE

$y_1=\frac{a-b}{2}$

$X_1=\frac{\pm a}{2b}\sqrt{3b^2+2ba-a^2}$

$H = a+X_1$

$H = a+\frac{a}{2b}\sqrt{3b^2+2ba-a^2}$

$H-H = a-b\pm\frac{a}{2b}\sqrt{3a^2+2ab-b^2}\pm\frac{b}{2a}\sqrt{3b^2+2ba-a^2}$

FIG. 6—DRAWING SHOWING HOW THE AMOUNT OF ERROR IN AN ELLIPTICAL OBJECT IS DETERMINED

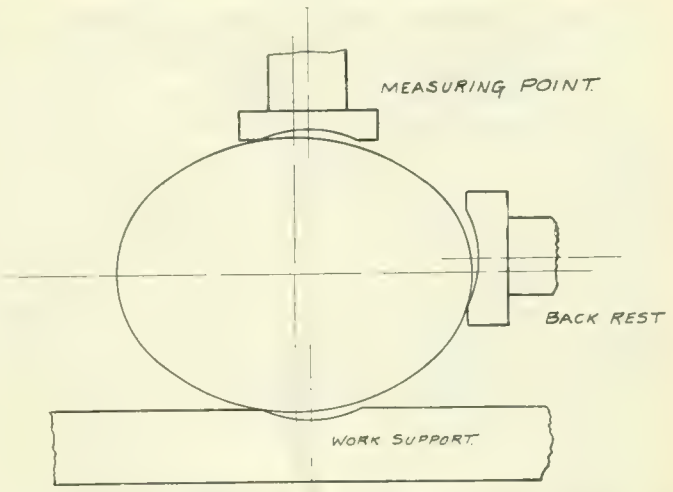


FIG. 7 DRAWING SHOWING HOW ERRORS OCCUR AS A RESULT OF WEAR OF THE MEASURING POINTS

Fig. 6 shows the amount of error in the reading of both the highest and the lowest points and, although this particular error is very large, their difference in readings is very close to the actual amount the specimen is out-of-round. Unfortunately, the formula for the corrections comes out in an involved form that does not permit us to show the percentage of error readily. However, the correction necessary, due to the complications of the radius on the measuring point, is greater than the foregoing correction.

Now let us suppose that the instrument is not absolutely new but has seen enough service to show some slight wear on the three registering points; the support-plate, the back-rest and the measuring point. After 2000 pieces are measured on one of these machines, the wear is evident even though the points subjected to wear show a scleroscope hardness as high as 90. This is a natural condition, as the pressure is very concentrated due to the bearing at all three points being a point of tangency.

The conditions shown in Fig. 7 now take place. With the major-diameter horizontal, the point of contact with the back-rest is either off the lowest point on the edge of, or entirely outside, the worn groove; this results in a lower reading than the true reading, due to the abnormal amount the measuring point is off-center. On the work-support, the piece is again either off the lowest point on the edge of, or entirely out of, the worn groove; this results also in a higher reading than the true reading, and the same condition is true at the measuring point. Hence, we see that one worn point contributes to a lower reading, while the two other worn points contribute to a higher reading. With the specimen in position with the major-diameter vertical, the results obtained are similar. The amount of error in the indicator-readings depends again on two quantities: the amount of out-of-round and the amount of wear. Inasmuch as the former quantity is unknown and the latter quality unknown or at least varying constantly, the results obtained cannot be corrected by any set mathematical formula and the correction must be obtained by checking with known-diameter master-pieces in the manner described.

CONCLUSION

This discussion demonstrates that an out-of-round surface requires a checking instrument having opposed measuring-points if the number of high-spots is even

and a checking instrument with 3-point contact with one point located on the centerline between the other two if the number of high-spots is uneven.

Another word of caution may be added concerning the use of the 3-point method. For close work, the angle between the three points of contact must be selected according to the number of high-spots. This is due to the fact that the high-spots are not points, nor the low-spots straight lines, and it easily is possible to select an angle that would not register on either the highest or lowest points.

This paper is not to be taken as an indictment against these various methods of inspection or even an implication that these methods are not the best that have been yet brought forward. It is meant to point out that the various indicator-readings require correction to produce correct results. It was also intended to bring out the fact that there is still considerable room for improvement of these instruments to eliminate some of our present difficulties. In connection with this, I suggest three items that probably are worthy of consideration by the manufacturers:

(1) A flat measuring-point large enough to reach the major diameter when it is off-center with the measuring point due to ellipticity

(2) A revolving characteristic of the measuring point to promote even wear

(3) A corrected indicator for use with the 90-deg.-angle V-block, thus eliminating correction by the operator

TRANSPORTATION

NO country in the world has the possibilities for efficient, modern transportation which we have. We must realize upon those possibilities. Our one great difficulty has been that we have grown at such an astonishing rate that our facilities have lagged far behind. Thus, in the motor field, while from 1910 to 1922 there has been an increase of 2450 per cent in the number of vehicles, and a far greater increase in mileage traveled and tonnage hauled, all of our efforts have failed to provide an adequate increase in our roadbed facilities in the same period, and at our present rate it will be 10 years before the United States can hope to arrive at a rounded-out highway system.

While freight cars have been increased in number by 23 per cent in the last 10 years, and the aggregate tractive power of locomotives 41 per cent, the Country is offering the railroads 60 per cent more business than ever before. Since the whole structure of business activity rests upon transportation, it is evident that we must use those facilities which we have in the most efficient way, unless the Country is to suffer from tremendous losses.

The actual competition between rail and motor carriers today is negligible and where it does exist it is largely due to the fact that the rail lines, suffering from undue regulation and cramped beyond reason financially, have been unable to provide desired facilities.

Responsible railroad executives have said that 25 per cent of railroad equipment is absorbed in the haulage of less than 5 per cent of the commodity movement and that it returns but about 10 per cent of the revenue. This is the less-than-carload movement in which is involved most of the terminal troubles to which the railroad men of the present generation have fallen heir. Terminal facilities, taken to mean all other than main line facilities, another authority has said, represent about 50 per cent of the total capital investment of the rail lines.

The operation of the truck makes possible new extensions of the field of our waterways. One of these is the vehicle used as a flexible medium of interchange between water and railheads. Another is the development of a pick-up and distribution service tying industrial and agricultural areas to inland and coastal shipping points.

While we now have some 350,000 miles of improved highway, 259,000 miles of railroad, 18,000 miles of interurban electric lines and 15,000 miles of inland canals and waterways, none of the older forms of transport can reap the full benefit from highway transport until a much larger percentage of our 2,800,000 odd miles of highway is made ready for constant traffic.

Government surveys in Connecticut, Tennessee, Maryland, and elsewhere show conclusively that by far the largest percentage of traffic even over our main highways is purely local. Highways, paralleled by other carriers in many instances but still largely destined for "feeder" uses, must be improved in every State in order that the rail, water and electric lines shall realize their full volume of travel; and more important, that the public shall derive the benefit of lowered transport charges which logically and naturally follow improved highways.

A study made from government figures by John E. Walker, formerly tax advisor to the Treasury, shows that the rail lines contributed approximately $304,000,000 in taxes in 1922. Motor users paid special taxes of $340,000,000 in 1922, or the equivalent of nearly one-half of the total highway construction and maintenance bill of the Nation, estimated at $742,000,000. Of that amount, $120,000,000 were discriminatory taxes levied by the Federal government and exactly comparable to those railroad taxes which, also growing out of the war, were repealed by a recent session of Congress.

The user should pay a fair charge for service rendered. But those taxes which are levied for construction or which do not go into highway work at all constitute the payment of general benefits through special levies which add materially to the cost to the public of this form of transportation.

Other large taxes are assessed against the electric lines and other carriers, yet inevitably the consumer must pay. In all these cases, then, we have an artificial barrier imposed in the way of efficient transportation at the lowest cost to the using public.—From an address by Roy D. Chapin before the Chamber of Commerce of the United States.

MOTORSHIPS

THE outstanding feature of new orders for British shipbuilding placed during the past 6 months is the growing share of motorships in the total tonnage booked. It might almost be said that the demand for motorships has recently kept the activities of British yards. The details issued by Lloyd's underwriters are given in the accompanying table.

In addition to those already launched, contracts have been placed for many large motorships, on which work has not yet been started. Among these are

GROSS TONNAGE OF MOTORSHIPS UNDER CONSTRUCTION

	Last Quarter of 1922	First Quarter of 1923	Second Quarter of 1923
Clyde	77,815	76,825	92,380
Belfast	.....	19,000	41,000
Tyne	15,200	17,700	32,865
Other Yards	32,335	44,259	55,029
Total	125,350	157,784	221,274

The Motorbus as a Transportation Medium

Discussion at Annual Meeting of American Electric Railway Association Held Last Month at Atlantic City

THE motorbus was probably the most conspicuous feature of the discussions presented and the exhibits made at the 42nd Annual Convention of the American Electric Railway Association and its affiliated bodies held at Atlantic City, N. J., on Oct. 8 to 12. A score or more of companies exhibited complete buses or unit assemblies therefor. Their efforts resulted in the largest and most interesting motorbus show that has ever been held in this Country.

C. D. Emmons, the retiring president of the Association, enlarged upon the fact that the motorbus is finding its place and rendering great service in the solution of the transportation problem. More than 100 electric railways are using approximately 1000 buses. The electric street-railway industry has 44,000 miles of track, employs 300,000 persons directly and furnishes part or whole-time employment to 500,000 more, transports more than 15,000,000,000 persons annually and represents an investment of between $5,000,000,000 and $6,000,000,000.

Alfred Reeves, general manager of the National Automobile Chamber of Commerce, gave an address on the Coordination of Electric-Railway and Bus Transportation. He said that the spirit of the motorbus industry is that of cooperation. He pointed out that low cost of operation is not the sole consideration in bus operation, the public being willing to pay 10-cent fares for service it considers good enough; and expressed the opinion that in general bus lines should be operated by the electric traction interests. In connection with a large portion of the public being accustomed to ride on rubber tires, he spoke of the contest between rubber and the iron rail. He propounded the question, If the bus had come first, would the trolley car have been developed? What the public wants is service and adequate service can be given only through utilization of both the bus and the trolley car. The natural fields of each should be defined as accurately as possible. Mr. Reeves said that the failure of bus lines in various cities is not significant, as the operating companies were organized in undue haste and without proper planning.

As was stated by L. S. Storrs, president of the Connecticut Co., the outstanding feature of the meeting, at least in connection with bus operation, was the conferring of representatives of the street-railway field with those of the automotive field, through their respective organizations. President Alden, of the Society of Automotive Engineers, discussed a report on bus operation that had been prepared by a committee of the American Electric Railway Transportation and Traffic Association, an affiliate of the American Electric Railway Association. It was set forth in this report that public authorities are gradually bringing order out of the chaotic condition which the jitney introduced into the transportation field 7 or 8 years ago. The committee presented data on bus operation that had been secured from street-railway companies. It was stated that the experience of these companies had been comparatively short and that none of them desired to go on record as being confident of having solved the various problems involved. The report was completed prior to July of this year.

The committee obtained information as to the class of service operated from 17 street-railway companies. To establish a relation between the class and the amount of service and the data that follow for each company, Table 1 was compiled.

Seven of these companies operate exclusively on city routes. Four companies operate exclusively in suburban service; two exclusively in interurban service, two in city and suburban service, one in city and interurban service and one in city, suburban and interurban service.

TABLE 1—DATA ON BUS SERVICE OPERATED BY 17 STREET-RAILWAY COMPANIES

Company	Class of Service			No of Buses Operated		Average Daily Mileage per Bus Operated
	Supplementary	Feeder	Independent	Base Schedule	Peak Schedule	
A	....	Yes	....	2	3	100
B	Yes	Yes	....	1	1	153
C	Yes	Yes	....	21	27	81
D	....	Yes	....	6	7	148
E	....	....	Yes	1	1	185
F	....	Yes	....	5	8	70
H	....	Yes	Yes	16	21	120
I	Yes	Yes	....	18	8	161
K	Yes	Yes	Yes	7	10	151
L	....	Yes	....	2	3	74
M	....	....	Yes	4	7	145
N	....	....	Yes	5	7	127
O	....	....	Yes	6	7	96
P	Yes	Yes	Yes	66	70	166
Q	Yes	....	....	6	10	216
R	....	....	Yes	12	16	153
S	Yes	Yes	Yes	9	9	....

Among the reasons given by the railway companies for the inauguration of bus service were the following:

> We were compelled by prohibitive cost of new paving and track work to substitute bus service for trolley service on two feeder-lines.
>
> To give residents of one city better service to another via a shorter route and provide service to people residing and working between the two towns.
>
> Our company was confronted with serious competition from buses and we inaugurated our original bus-line to determine what the possibilities of bus service were and also to protect ourselves against unwarranted and unregulated competition. As a result of the operation for a period of over 7 years, we have built up a service that is paying its way under present rates of fare and providing transportation to a district that needs and appreciates it.
>
> We have considered that with the right to a monopoly of transportation went the obligation to furnish reasonable and adequate transportation facilities wherever they were needed, and the obligation to use whatever motive power was best adapted to the conditions.
>
> Stage-line service was inaugurated to make possible through service between two cities, a route mileage of approximately 100 miles, by which the work of carrying passengers could be done with motor stages with a much smaller investment than by rail.
>
> The physical situation of the line prevented the giving of a street-railway service that was rapid enough to suit those whose necessity or convenience required quick transportation between the towns served. In effect the coach transportation is a limited street-railway service supplementing the slower service given by street cars regularly. However, the coaches probably afford a more pleasant ride and through the advance sale of reserved seats, it is very convenient for prospective passengers to avail themselves of this service.

The committee pointed out that if a street railway company adopts the policy of providing for all of the transportation needs in the territory served, the possibilities of the bus as an aid to the carrying out of such a policy cannot be overlooked. As to the matter of substituting bus for rail service, this is always a problem of economics. In the case of a line requiring heavy rail renewals with heavy rehabilitation or paving charges, the bus provides a means of continuing service at an expenditure for equipment that is much below the cost of plant renewals or paving.

The committee expressed gratification that street railway companies are discarding the truck chassis and adopting the improved types as rapidly as the builders are developing them, and stated that, in the further development of the bus, simplicity and accessibility should be the chief aim of manufacturing engineers. It should be borne in mind that ordinary running repairs are made without removing the body and therefore, easy removal and replacement of parts from underneath the chassis should be made possible. It is very desirable that time out of service be the minimum. A unit power system will meet this requirement best. To facilitate this, attention should be given to standardization.

Consideration must be given also to the peculiar requirements of a vehicle operated in passenger service, such as a low center of gravity, flexible and gear designs that are suitable for frequent stopping and starting, adequate and economical power and spring-suspension to give the maximum riding-comfort under varying load conditions.

The report did not cover body development in any detail as the committee believes that each operating company will work out its own requirements in this connection. In general, the committee felt that no reason exists why the electric-car body designs cannot be used as a base from which to develop bus bodies that will give public satisfaction from the standpoints of safety, comfort and convenience. There will, of course, always be cases that will require specific treatment based on the particular transportation problem to be solved.

The majority of the bus-lines reported on were operated by the organizations that manage the respective street-car systems. In general, the buses were maintained by the railway companies, specially skilled mechanics being employed for work on the buses, which it is appreciated are an essentially different type of equipment.

Most of the street-railway companies are operating buses on such a small scale that in the committee's opinion the companies would not be warranted in incurring the increased overhead and maintenance costs that would be necessary if their bus work were separated entirely from the electric-car work. However, this practice ceases to yield the maximum efficiency and economy the moment the number of units becomes large enough to justify keeping a separate corps of mechanic inspectors and cleaners busy during the entire working day. Bus-chassis maintenance requires an entirely different kind of training than electric-car maintenance, and if an attempt is made to spread the supervision of maintenance over both types of equipment, the maintenance of both will be unsatisfactory. Owing to the wide diversity of local conditions, the committee was unable to suggest a standard maintenance organization. The observation was made, however, that, inasmuch as bus bodies are now following very closely the type of construction used in electric-car bodies, body maintenance can be conducted most efficiently and economically by supplementing the regular body-maintenance force. Several of the railway companies have contracted or plan to construct separate bus garages.

In the majority of the cases the rates of fare for the street-car lines apply to the buses operated by the traction companies. Transfers are usually issued.

Depreciation

Among the items for allowing for depreciation of the buses were:

- 4-year life; most of the buses will last longer than 4 years with present maintenance standards, but it is believed improvements in bus design will render present buses obsolete within 4 years
- 25 per cent depreciation
- Estimated life of chassis up to 2-ton, 150,000 miles; 2-ton and over, 200,000 miles
- 5-year basis
- 5-year basis; 1 12 of 33 per cent of book value, less $500 salvage value, charged-off per vehicle per month
- Salvage value of 20 per cent of original cost at end of 3 years; 80 per cent charged off in 3 years
- 10 per cent of original cost taken as salvage value; balance of 90 per cent charged off in 6 years
- 80 per cent of original cost charged off in 3 years
- 25 per cent per year; buses average 60,000 miles per year
- 5-year life, 5-per cent salvage, 19 per cent per year depreciation

None of the companies was in a position to give definite information as to the life of bus equipment. All of the depreciation methods are still in the tentative stage. The committee felt that as the life of tires is relatively short the cost of them should not be included in the principal amount to be depreciated; and that, because of the many variable factors involved in the physical depreciation or wear-and-tear of a bus, it is difficult to formulate standard practice for charging depreciation in this connection. In a new art, of course, consideration must be given in calculating depreciation charges to obsolescence and inadequacy.

The committee reported that with one exception the information received indicated that the public is entirely in favor of bus operation by the street-railway companies.

Operating Costs

With regard to the table of cost of operation submitted by the committee and reproduced as Table 2, it was stated that this presented the results of such limited experience by all of the companies that it did not indicate clearly what should be expected in the future. None of the companies has been operating much longer than 1 year. Their equipment was new and did not require heavy expenditures for repairs or renewals for some months. The equipment consisted of chassis of from ¾ to 2½-ton carrying and of from 12 to 25 seating capacity, the total weight of the buses varying from 3000 to 10,000 lb. Most of the tire equipment was of the pneumatic type.

The committee said that, on account of the lesser seating-capacity of the bus, the cost per passenger is considerably higher than in electric-car operation. The average cost per bus-mile, incuding taxes and estimated depreciation, based on the figures furnished to the committee, is 24.6 cents. No results from the operation of double-deck buses were included in the compilation and it was assumed that the average seating-capacity per bus was 25. On this basis the cost per seat-mile of bus operation was 0.98 cent. Data obtained from 10 companies operating one-man trolley cars showed an average cost per car-mile of 25.7 cents, including depreciation based on the estimated life of the equipment and taxes. These cars had an average seating capacity of 42, and the resulting cost per seat-mile was 0.61 cents. On this basis the cost per seat-mile of bus operation is approximately 60 per cent greater than in the case of the one-man electric car. The figures did not, however, include a return on the value of the property.

The committee referred to the fact that in some localities the law prevents the carrying in buses of few if any more passengers than seats are provided for. In this respect the street-car is more elastic. In general, three buses are required to furnish the same number of seats as two trolley cars.

The committee of the Transportation and Traffic Association that made the report referred to above was constituted of, among others, representatives of the following companies:

TABLE 2—OPERATING RESULTS PER BUS-MILE REPORTED BY STREET-RAILWAY COMMITTEE

Company	A	B	C	D	E	H	I	L	K	O	O	R	
	1-1-23 to 5-31-23	1-1-22 to 3-31-23	7-1-22 to 3-31-23	5-26-22 to 3-31-23	1-1-22 to 3-31-23	3-1-22 to 3-31-23	1-1-22 to 3-31-23	12-1-21 to 11-30-22	7-3-22 to 3-31-23	7-15-22 to 12-31-22	1-1-22 to 12-31-22	4-1-22 to 3-31-23	Weighted Average of All Companies
Transportation Revenue	Cents 26.50	Cents 21.18	Cents 28.67	Cents 13.42	Cents 25.99	Cents 25.25	Cents 19.23	Cents 6.11	Cents 20.84	Cents 29.79	Cents 17.41	Cents 26.28	Cents 21.18
Other Revenue			0.60	0.04		0.02	0.06		0.04	0.86	0.51		0.21
Total Revenue	26.50	21.18	29.27	13.46	25.99	25.27	19.29	6.11	20.88	30.65	17.92	26.28	21.39
Maintenance, Excluding Depreciation and Tires	3.83	1.95	4.50	1.62	3.02	6.56	4.00	2.62	5.42	6.71	2.97	2.61	4.20
Tires	1.50	1.94	1.49	1.32	0.85	2.48	2.43	1.87	1.65	2.50	1.51	0.47	1.88
Depreciation	3.00	2.68	3.88	3.25	2.29	3.96	2.67	7.19	3.05	2.87	2.68	1.03	3.08
Wages of Bus Operators	7.68	5.65	6.49	6.09	7.03	6.91	6.05	6.43	5.64	4.55	3.82	6.04	5.74
Other Conducting Transportation Expenses	4.83	3.26	10.19	5.84	7.18	7.67	5.06	4.60	7.01	3.33	3.29	7.21	5.95
Injuries and Damages, Insurance, Other General Expenses	3.25	2.52	3.44	0.77	6.56	3.04	3.93	0.57	0.74	5.32	3.64	2.56	3.10
Total Expense	24.09	18.00	29.99	18.89	26.93	30.62	24.14	23.28	23.51	25.28	17.91	19.92	23.95
Net Operating Revenue[1]	2.41	3.18	*0.72*	*5.43*	*0.94*	*5.35*	*4.85*	*17.17*	*2.63*	5.37	0.01	6.36	*2.56*
Taxes	0.92	0.25	2.10	0.60	0.15	0.24	0.92	0.65	0.05	0.18	0.40	0.49	0.65
Operating Income[1]	1.49	2.93	*2.82*	*6.03*	*1.09*	*5.59*	*5.77*	*17.82*	*2.68*	5.19	*0.39*	5.87	*3.21*
Operating Ratio	90	85	102	140	104	121	125	381	113	82	100	76	112
Bus-Miles	35,124	70,371	443,602	226,798	80,596	653,249	1,126,189	108,017	479,303	144,605	806,354	234,107	4,373,191(*a*)

[1]Deficits are shown in italics.
(*a*) Total for all companies

United Electric Railways Co., Washington Railway & Electric Co. (City of Washington), Pennsylvania & Ohio Traction Co., Milwaukee Electric Railway & Light Co., United Railways & Electric Co. of Baltimore, Connecticut Co., Virginia Railway & Power Co. and Boston Elevated Railway Co.

President Alden's Discussion

After expressing appreciation of the opportunity to participate in the meeting as a representative of the Society of Automotive Engineers, President Alden said:

We were honored by the presence of President Emmons, of the American Electric Railway Association, at the Cleveland meeting of the Society of Automotive Engineers last spring. Our two organizations should work hand-in-hand in solving the problems presented by the new form of transportation under discussion today. It is none too early for the designer and the builder to get together with the user. Only by sincere and hearty cooperation can satisfactory progress be made. Plain speaking on both sides, if of a constructive nature, should be welcomed by both sides. Destructive criticism by either party will not only be a waste of time, but impede cooperation; and cooperation is the keynote of success. I feel that at this, our first official appearance with you, we should not be too argumentative. It is of far more importance to the success of this young project that we get together, as we are doing now; try to understand each others' viewpoints more clearly; approach the problem in a cordial spirit of give-and-take; and assume that the other fellow knows his own problems pretty well. Then we can be of the greatest mutual assistance.

I shall not discuss at length the advantages of bus transportation or try to prove that it is the last word in passenger transportation. All new things remain if they fill a need and only insofar as they do fill a need. We could get up no argument on the fact that present-day railroad and street-railway transportation do not meet all passenger-transportation needs. The activity of your association, as evidenced by the report under discussion, proves this. A need for motorbus transportation exists. The problem is to define that need and find means to meet it.

Your committee is to be congratulated on the breadth and scope of its investigation. This should furnish an excellent foundation for future endeavor. My remarks will be confined largely to the subject of that report.

Judging from the phenomenal growth of motorbus transportation, in both city and inter-city work, it is obvious that the motorbus does fill a certain need in the life of the Nation. Here and there it will be overdone. At times it will be foolishly handled. Out of all, however, will gradually emerge a new form of passenger transportation, giving a service the street-railway never can give. It will create its own traffic in many places, because of its unique characteristics. In the last analysis, however, it will remain only when and where it can make money for the operator. This is the final test. It must be a revenue producer.

I wish to give credit for great assistance in preparing these notes to the publishers of *Bus Transportation*, G. A. Green, of the Yellow Coach Co., Chicago, and F. C. Horner, of the General Motors Corporation. Your attention is directed to a paper[2] presented by W. P. Kennedy before the Metropolitan Section of the Society of Automotive Engineers on the subject of trolley buses and to the discussion[3] of this paper, which was published in THE JOURNAL recently. In both the paper and the discussion much valuable information will be found.

Proceeding now to the report proper, the first thing that struck me was that the companies investigated were all street-railway companies. I can understand readily that to make as complete an investigation of the operations of outside or independent companies might be very difficult, as well as contrary to the policy of your association. It seems, however, that the picture presented by the report would have been somewhat different if independent companies had been canvassed, because a great many independent bus-companies are making money.

The general summary of the results reported by your 12 company-members shows a net loss. We should not jump to the conclusion that this is a chronic and expected condition. Your report shows that 4 out of the 12 companies received revenue in excess of expenses. Two of the 12 had such ridiculously low revenues that it seems that they tried to operate under impossible conditions. It appears to us that your association ought to extend its official investigations to independent companies. It is realized, of course, that the

[2] See THE JOURNAL, September, 1923, p. 179.
[3] See THE JOURNAL, October, 1923, p. 322.

[illegible] of the which many independent companies operate are free from some of the handicaps with which the street-railway companies are saddled. On the other hand, I have always been a firm believer in trying to get a pretty clear idea of what the other fellow is doing and making it a matter of permanent record.

The committee's investigation covered only single-deck buses. In many places a double-deck bus is suitable, as evidenced by its success in London, New York City, Chicago and Detroit, in all of which cities revenues exceed expenses by a comfortable margin.

It is gratifying that, in spite of the rather gloomy picture painted, the consensus of opinion among your operators seems to be that the motorbus is here to stay. The early years in any undertaking are generally painful. They appear to be so in this case. However, I am informed that in 1921 composite results of 52 city railways showed 46.5 cents per mile revenue and 45.7 cents per mile expense. This is not a particularly rosy picture either.

In analyzing the reasons cited by the companies investigated as to why motorbus transportation was taken up, considerable light is thrown on the subject. These reasons can be roughly classified as follows:

(1) To meet competition
(2) To give better service
(3) To fulfill an obligation resting upon a transportation system which has a monopoly of transportation
(4) To feed new territory at a minimum of investment expense

These are all very sound and economic reasons. I venture to suggest that in some cases at least the proper equipment was not chosen. Too much care cannot be given to this matter. Differences in types of vehicle may easily mean the difference between red and black figures at the end of the year.

Proper routing is another important element, probably not very well understood as yet. I have heard of one case in New England in which a study of this member of the equation changed a loss into a profit.

Speed of operation, a very important factor, is not covered adequately in the report. A change in engine size, gear reduction, or the like, which would raise the average speed of a city bus, even so much as 10 per cent, might also change a loss into a profit.

Little appears in the report on special forms of equipment for special services as such. These special services may, when properly catered to, mean the difference between a deficit and a surplus. The motorbus is excellently adaptable to express service, which even double-track street-railways cannot give. Double-deck buses, furthermore, create a traffic of their own, as people delight in the upper-deck comforts. They leave their motor cars at home and come into town on the bus. We know this from the results in New York City, Chicago and Detroit. The bus attracts the sightseer as no trolley car or single-deck bus can. I mention these points simply to bring out the fact that if all of these features of motorbus transportation are studied and their revenue-producing capacity made available, the net operating financial result can be enormously altered.

We have heard in Detroit that 25-passenger one-man buses can be operated for very much less money per mile than even the small one-man street cars, and they are the last word necessary in developing territory or augmenting [illegible] the street-railway equipment of the city.

I [illegible] a complaint from your committee that much of the equipment that the members of your association have been compelled to buy was little more than [illegible] experiments. The motorbus [illegible] in [illegible] conditions is nearly all [illegible] in regard to the kind they [illegible] of the companies, of course, have recently made up and developed special equipment. Bus service demands special equipment from end to end, designed primarily for bus service, the conditions and requirements of which are totally different from those obtaining in merchandise transportation.

Your practice shows a wide variation as to depreciation. Surely the bases given can be made more nearly uniform. On the whole, it seems that the figures taken are unnecessarily high. With the right equipment, that is one that will not soon become obsolete, a 10-year life is not too much to expect, when the vehicles are operated under good maintenance practice. The table prepared by the committee gives depreciation as about 13 per cent of the total expense on the average. This seems high. Of course, in the early days of any project it is wise to err on the safe side, but it seems that there were enough well established data, as evidenced by the London General Omnibus and the Fifth Avenue Coach Co. practice, to indicate 7 or 8 per cent as being an adequate depreciation. I note that your committee advises its members so study carefully the factors governing depreciation. This is very timely advice.

The earnest purpose of your association to take up the new instrument of transportation that our industry has produced, and to give it a fair trial, is very gratifying. We have unlimited confidence in its future. We know that we are just beginning to understand the problems to be met. We appreciate pretty well the necessity of special equipment. Working with you, we can more and more meet your requirements. On the other hand, you will have to give these new things a fair chance to show what can be accomplished, and to plan their operation, as you have done in most cases, with the idea of making them financially successful. The motorbus has many fundamental characteristics that make it excellently adaptable to filling a public need. It should enlarge your field of operations; enable you to hold business you otherwise would lose; and, properly combined with your railway operations, lead to ultimate economy of operation of the entire system.

I think it is the general opinion that the highest usefulness of the motorbus is attainable by street-railway organizations in conjunction with the rest of their equipment, rather than by competitive organizations.

The Society of Automotive Engineers hopes that this meeting today is just the first step along the road of cooperation that will be increasingly profitable to both yourselves and ourselves. We stand ready to do our utmost wherever we can be of assistance. It will give us great pleasure to have some representative of your organization present your problems to us at each of our transportation meetings, which we have decided to hold at least twice a year. I believe that the closest possible official cooperation between our two organizations is highly desirable. Our organization will leave no stone unturned to effect this cooperation.

Standardization Activities

The importance of the formulation and the reduction to practice of proper mechanical standards was emphasized repeatedly during the meeting, the object to be attained being a reduction of cost in the design, construction and operation of buses, as well as the enhancement of the quality of the product. At the close of the session at which the committee's report on bus operation was discussed, H. B. Keenan, superintendent of the bus division of the United Electric Railway Co., proposed that the American Electric Railway Association go on record as approving S. A. E. Standards and the standards of the affiliates of the Association. He advocated full interchangeability of assembly units, including engines, and simplification of practice with regard to screw threads. After stressing the importance of accessibility of bus parts in general, he expressed the opinion that

depreciation of 20 per cent per year is not reasonable and can be reduced. He recommended strongly that committee organization be effected to take up standards work before the bus industry becomes too old to put into effect promptly standards that may be established now. In this connection the full cooperation of the automotive industry was sought. In fact, there was much clear and striking evidence that the street-railway men desire to work closely with the representative organizations in the automotive field in the solution of various problems being encountered in the fast-growing and decidedly important bus industry.

Immediately after the conclusion of the session, President Alden addressed the executive committee of the American Electric Railway Association on the matter of joint procedure in the formulation of motorbus engineering standards. He stated that the Society had already decided to call a preliminary conference on this subject, with the purpose of organizing a special committee to study it. He asked that the American Electric Railway Association designate representatives to take part in the preliminary conference. This was done promptly, a committee being named by the street-railway interests.

BENZOL AS ENGINE FUEL[1]

THE use of light oil as engine fuel is of importance in districts adjacent to by-product coking operations from which a reasonable proportion of the local demand may be supplied. Furthermore, the certainty of diminution of petroleum resources in the relatively near future demands the utmost utilization of gasoline substitutes from the distillation of coal, as well as from other sources.

In ordinary coking practice from 1½ to 3 gal. of refined motor benzol is obtained per ton of coal carbonized. The crude benzol is yellow in color and contains sulphur compounds that corrode copper and brass; it also contains unsatured bodies that oxidize and polymerize on standing, producing sediment and forming gummy deposits. These along with the other impurities are highly objectionable when the benzol is used in internal-combustion engines and therefore must be removed by further refining and distillation.

How the Fuels Were Tested

To investigate the practical utility of these fuels the Bureau of Mines, in cooperation with the Davison Chemical Co., made engine tests on motor-benzol fuels refined by various methods. The testing equipment consisted of a four-cylinder, 1915 model, Lycoming engine, with cylinders of 3½-in. bore and 5-in. stroke. The engine was directly connected to a Sprague electric dynamometer and revolution counter, from which the brake load and the horsepower developed could be obtained. The speed of the engine was kept constant and an orifice plate inserted between the carbureter and the intake-manifold gave a non-varying throttle adjustment so that the amount of the fuel-air mixture entering the engine would be approximately constant. The fuel was supplied from a large graduated tank, and a record was kept of the weight of fuel consumed during each test. The air-fuel ratios 10.1 to 1 and 13.5 to 1, were calculated from an ultimate analysis of the fuel and the analysis of the exhaust gas. The testing period was set at 40 hr. at an engine speed of 100 r. p. m. The temperature of the cooling water flowing through the engine was kept at 150 deg. fahr., ± 1 deg. All readings were taken every 15 min., and samples of exhaust gas every hour. At the end of a run, the quantity of fuel consumed was measured; then the carbon was removed from the cylinder-head, cylinder block, spark-plugs, and piston-head and was weighed. The so-called gummy deposits, when present, were found to collect under the intake-valves, on the stems and in the intake-manifold, close to where the gas mixture entered the combustion-chamber. After each test these deposits were removed and weighed.

Performance of Different Fuels

The crude motor benzol used was a totally unrefined light oil direct from the wash-oil still of a large coke oven plant of the Koppers type. That portion boiling below 150 deg. cent. (302 deg. fahr.) was taken for the test. The run with this oil at a 10.1 to 1 air-fuel ratio showed that engine trouble was confined to gummy deposits sticking in certain of the intake-valves while the engine was stopped and became cold over night. At the end of the run, heavy gummy deposits were found in the intake-manifold and under the intake-valves. The deposits were hard and brittle and had little odor. With the 13.5 to 1 air-fuel ratio, considerable gummy deposits were noted in the intake-manifold and under the inlet-valves after a 16-hr. run.

It was concluded that crude motor benzol cannot be used satisfactorily in an internal-combustion engine until after certain compounds that form these gummy deposits are removed. These deposits, after a variable period of operation, prevent the valves from seating, cause the gases to pop back into the carbureter and eventually stop the engine.

The acid-refined motor benzol used was a crude light oil that had been washed with (*a*) sulphuric acid, (*b*) caustic soda solution and (*c*) water, and then redistilled up to a temperature of from 130 to 140 deg. cent. (266 to 284 deg. fahr.). With air-fuel ratios of 10 to 1 and 13.4 to 1, the engine ran satisfactorily throughout the full 40-hr. test, without any valve trouble. A very thin gummy deposit was found in the intake-manifold on two valve-stems, but the quantity was too small to weigh.

The crude benzol subjected to silica-gel refining was prepared from a new lot of crude light oil, which was distilled up to 143 deg. cent. (289.4 deg. fahr.). This distillate was vigorously agitated with 0.25 per cent of caustic soda in an equal weight of water. After ½ or 1 hr. of settling, the alkaline solution was carefully separated, and the benzol subjected to percolation through silica gel. This material had been finely ground, all passing through 150 mesh, and was freshly activated before being used.

With the silica-gel treated motor benzol and an air-fuel ratio of 10.4 to 1, no valve trouble developed during the 40-hr. run. A very small deposit was found in the intake-manifold, and a slight sooty deposit on the underside of the inlet-valve heads. The valve-stems were exceptionally clean; in fact, the inlet-valves and the intake-manifold were cleaner than in any previous test.

Conclusions

(1) Crude motor benzol cannot be used satisfactorily in an internal combustion engine

(2) Acid-refined or silica-gel refined benzols develop no engine troubles and are satisfactory to use therein, providing the refining process in either case is complete in removing the gum-forming constituents

(3) Variation in the air-fuel ratio in these tests showed no definite influence on the quantity of gummy deposits formed

(4) A motor-benzol fuel that gives an evaporation residue of less than 0.01 per cent by weight should not give gummy deposits in the intake-manifold and on the intake-valves, when used in an internal-combustion engine

[1] Synopsis of a monthly report of an investigation prepared by A. C. Fieldner and G. W. Jones of the Bureau of Mines Experiment Station, Pittsburgh.

Wage-Incentive Systems

By Eugene Bouton[1]

Production Meeting Paper *Illustrated with* Charts

NUMEROUS wage-incentive plans are now in operation in the various automotive and other industrial plants; but the proper system to install in a given plant, whereby unit costs will be maintained level and at the same time proper co-operation from employes will be obtained, has always been open to discussion.

One plan now in use by the company represented by the author is straight individual piece-work on small-parts operation where one, two or even three operations complete the particular part, and where only one or two operators are engaged in machining or assembling the particular unit; whereas, on the major machining and assembly units such as cylinder-block machining and engine or complete-car-assembly units group piece-work is employed throughout the entire plant.

By the installation of individual and of group piece-work, unit costs are maintained level at all times; in addition, the workmen employed are able to determine very easily by their own calculations what they have earned either daily or at any hour of the day. This is in direct contrast to other and more complicated systems wherein unit costs are not maintained over given periods and workmen in many cases are required to work for a complete pay-period without being able to ascertain their earnings over and above their guaranteed day-rates.

Still another feature of the group and the individual piece-work plan is the small clerical force necessary for the functioning of the system. Our company and its employes feel that the wage-incentive plans now in operation have met all of the principal objections generally experienced with other wage-incentive systems.

WAGE-INCENTIVE systems constitute one of the important problems of the industrial world. Many writers on wage systems, management and personnel administration cover their systems very well; but their articles are largely lacking in statistical information. In modern industry, the unit-cost of production is an important factor. It does not matter how much a man receives per hour or per day if his output is in proportion to his wages. There are many plants that are so well organized that they pay high wages and yet have a low production-cost, while other plants more poorly organized have a high unit-cost of production in spite of the fact that they are paying low wages.

Practically all managers of modern plants believe that some wage-incentive plan is necessary to attain the highest production possible. The subject of most discussion regarding wage-incentive plans is: What is the proper system to install? Many men state that standard time is the best, while it is claimed by others that straight piece-work, premium and the like are much better. It would be interesting indeed to survey all the plants in the automotive industry to determine what wage-incentive systems are in use, to tabulate them in detail and thus show exactly which systems are most favored. Many of the systems now in use are highly

GROUP PIECE WORK

OPERATION AND ROUTING SHEET

Date 6-6-23 Order No. 101

Name CRANK & EXHAUST MANIFOLD ASSEMBLY Part No. 7105A

Cost Item 32 1 1

1	Time for operations on Part No. 7105, Exhaust Manifold, & No. 7115 Intake Manifold and the Manifold Assembly to be worked on a group for the price per hundred Manifold as follows:-	1.14		(See below)
	Part No. 7105.			
	a. Bore exhaust out	18.6	700	Cincinnati Drill. Double Head Fixture
	b. Mill flanges	7.1	122	Cincinnati Miller Double End Fixture
	c. Mill face pad	7.75	101	#2 Cincinnati Mill. Double Head Fixture
	d. Drill (7) 17/64" holes	23.1	30	Cincinnati Drill Press Drill Jig.
	e. Mill air pad	21.8	240	#2 Cincinnati Mill Miller Fixture
	f. Drill & tap (4) 5/16"-18air pad holes for cover	22.9	273	Universal Radial Drill Holding Fixture Drill Jig.
	g. Cut (3) 5/16"-18 face pad holes and Drill for & tap (2) 5/16"-18 carburetor flange holes	21.6	322	Universal Radial Drill (2) Holding Fixtures (1) Drill Template Drill Jig.
	Part No. 7115.			
	a. Mill flanges	7.1	122	Cincinnati Miller Double End Fixture
	b. Mill face pad	7.75	101	#2 Cincinnati Mill Double End Fixture
	c. Drill (6) 11/32" face pad holes	22.4	36	Cincinnati Drill. Cross Drill Jig.
	d. Spotface (7) bolt hole bosses	20.1	122	Cincinnati Drill. Cross Holding Fixture
	Manifold Assembly			
	a. Assembly intake & exhaust manifolds	4.10		Assembly Holding Fixture
	b. Drill (10) 15/32" and (6) 7/16" flange holes.	19.5	119	Natco multiple Drill Intake Manifold Fixture
	c. Mill carburetor pad	20.9	325	#2 Cincinnati Mill Hold-in Fixture
	d. Drill (1) 25/64 holes for carburetor bolts and chamfer intake ports	16.9	133	Cincinnati Drill Holding Fixture

Remarks: All operations to be worked on 4 spindle mill the total allowance predicted upon the number of the workmen in the group to pay them their hourly rates.

Approved

FIG. 1. AN OPERATION AND ROUTING SHEET FOR GROUP PIECE-WORK

complicated and involve a large amount of clerical work and maintenance expense. Using such systems, the employer does not know with certainty in advance just what the direct labor-cost will be, nor does the employe know what his earnings will amount to in a pay-period. As a rule, costs and earnings are compiled at the end of a pay-period or every month.

Manufacturing conditions, as well as the manufacturing processes in the departments of a large plant, vary considerably and cause entirely different problems to arise. Therefore, a single wage-incentive plan which will fit all departments in an automobile plant satisfactorily is yet to be evolved. The straight piece-work system has been criticized severely by both employer and employe, sometimes unjustly because of the application of piece-work to operations which do not lend themselves to this form of wage-incentive. When the correct and applicable system is used, the opposition of labor is reduced to the minimum. However, there are many

GROUP PIECE WORK

OPERATION AND ROUTING SHEET

Date 9-21-23

Part Name CHASSIS, BODY, FINAL, SUB-ASSEMBLIES & WIRING GROUP Part No 75

Material ..... Model 32 Req per car 1 Sheet No 1

OPER. No	OPERATION	PRICE	HRLY PROD	TOOL No	TOOLS OR EQUIPMENT
1	The following operations are to be performed by the entire group:-	——			
	a. All operations on conveyor from spring mounting to finished car including spraying of chassis.				Assembly Track
	b. All sub-assembly operations excepting running boards and floor boards which are to be worked on individual piece-work.				Sub-assembly benches Wheel Department
	c. All body assembly, covering all model cars.				Body Department.
	d. Assembly all cables, ready for car; assemble all ignition & lighting wires ready for car, all models; assemble instrument panel complete; assemble dispatch switch.				Wiring Department
	NOTE:- The above price per completed car and is to be worked as a group covering all men working on operations or parts of operations described above. The total group earnings are to be pro-rated among the total number of men in the entire group according to the individual employee's day rate. This price applies to all model cars built.				

Remarks Approved

FIG. 2—ANOTHER GROUP PIECE-WORK OPERATION AND ROUTING SHEET

operations in connection with which straight piece-work is perhaps the best incentive-plan to apply. The same is true of other forms of wage-payment plans whenever one particular system is used throughout a factory.

A COMBINATION OF SYSTEMS

The company I represent has adopted the group piece-work plan for the major assembly units and machining departments, sample forms being shown in Figs. 1 and 2. Straight individual piece-work, a record form for which is shown in Fig. 3, is used for small parts on which the operations do not lend themselves very readily to group piece-work and which are, in fact, apart from any group of men or operations which involve only one, two or three operations to complete the part. The piece-work prices are established from data obtained in an elemental time-study. The time-study record is shown in Fig. 4.

The group piece-work plan is fundamentally the same as straight piece-work. A time-study of all the operations in the entire group is taken, reasonable allowances for fatigue, tools and contingencies are made, and the price is set based on the additive time. The group earnings are derived from the number of accepted finished units multiplied by the unit price. The individual workman's earnings are prorated out of the group earnings based on his hourly rate and the number of hours worked. A simple method of figuring the individual earnings is that: The total group piece-work earnings divided by the total day-rate earnings of the group equals the factor by which is multiplied the workmen's day-rate earnings; this gives his prorated piece-work amount. Thus,

$$W = T/D \times H \times R$$

where

D = Total group hourly-rate
H = Hours worked
R = Hourly rate
T = Total group-earnings
W = Employe's total earnings

DIFFERENTIATION OF HOURLY RATES

One of the important factors in the successful operation of the group plan is the differentiation of hourly rates. The most careful judgment should be exercised in rating the men according to their ability and to the skill required to perform the respective operations. All unskilled operators, including new men, should receive the minimum hourly-rate; skilled and semi-skilled workmen should be rated accordingly, above the minimum rate. Maximum and minimum hourly-rates are specified by the management and all rates must be within those specified. If a workman requests an increase in hourly rate, and the increase is favorably recommended by the department foreman, this can be granted without increasing the cost of the unit, as the workman simply receives a higher prorated share of the total group-earnings. This has been an important and satisfactory factor in the revision of rates, and balances better the earnings of the various operators according to the work which they perform.

NUMBER OF MEN REQUIRED

Another feature of the group piece-work plan is the immediate determination by the foreman of the number

INDIVIDUAL PIECE WORK

OPERATION AND ROUTING SHEET

Date 8-2-23

Part Name CRANKSHAFT BEARING CAP - FRONT Part No 20123

Material Aluminum Model 32 Req per car 1 Sheet No 1

OPER No	OPERATION	PRICE	HRLY PROD	TOOL No	TOOLS OR EQUIPMENT
1	Mill bottom surface	.0060	83	22	Cinn. Vertical Mill Milling Fixture
2	Drill (4) stud holes	.0130	47.4	120	Natco Multi. Drill Drilling Fixture
3	Ream (4) stud holes	.0077	83.2	568	Canedy Otto Drill Press
4	Spotface (4) stud holes	.0092	70	568	Canedy Otto Drill Press

Remarks Supersedes sheet dated 4-27-23 Approved

FIG. 3—OPERATION AND ROUTING SHEET FOR INDIVIDUAL PIECE-WORK

of men required to produce according to any given schedule of units. For example, if it requires 100 men to finish 100 units per day and the schedule of production should drop to 75, practically 75 men would be required to produce 75 units. However, if the schedule should drop to 50, it would, in actual practice, require a few more than 50 men, due to the fact that each workman would have to perform more operations and individual production would be limited for that reason. Likewise, when the schedule of production is increased, say to 150 units per day, it would not require 50 additional men in actual practice.

Unit-Cost

The group or cost price of each unit should be based on a schedule as nearly uniform as it is possible to set, and a slight fluctuation either upward or downward would not affect the price. Any wide variation in production would tend to change the original rate, and necessitate a slight change in the piece-work price of the unit. Little has been said by others about this feature of group work, but it is a factor to be reckoned with at certain times of the year when production fluctuates. However, how far from the original schedule we can go, either upward or downward, before the price is affected, is to be determined in any individual plant wherever the group prices are established.

Adding New Men

When a new employe is added to the group, he can be allowed to work in the group 2 days at his regular day-rate before participating in the group earnings. After that period he is prorated among the group. Should the new employe be too slow, or not satisfactory to the rest of the group, he is taken out. In this way the company bears a portion of the expense of breaking-in the new man, and so does the group. At our plant, as a rule, when a new employe is put into the group, he is started-off at the group price. In cases where the labor turnover would be exceedingly high for a short period, one way to handle the new employe is to place him on his hourly day-rate for a period of 2 or 3 days and deduct this amount from the group earnings; but, as stated previously, we have never had to apply this feature.

The employes are desirous of earning as much money as possible; therefore, their interest in the group is also to keep the number of employes down to the minimum. The spirit of teamwork is developed in each group, and the inefficient workers are eliminated by the other group-

Fig. 4—The Time-Study Record

Inspector's Report

Date ..... Part No ..... Group .....

Quantity	REJECTED		SCRAPPED	
	Quan	Last Operation	Quan	Last Operation

Remarks

Note This report to be turned into time office not later than 8 A M following day

..... Inspector

Fig. 5—Inspector's Report Blank

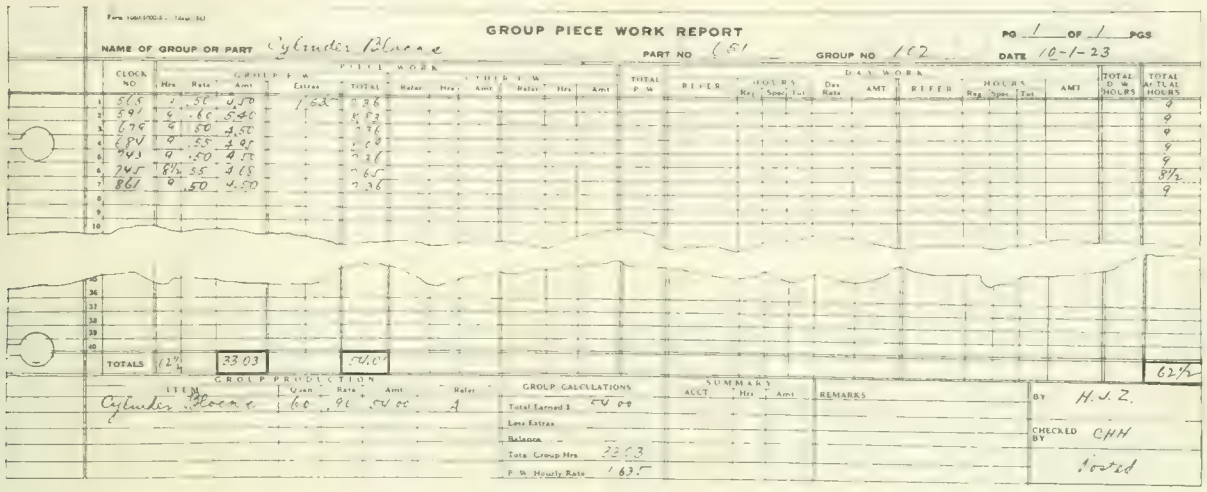
workers; this relieves the foreman to some extent of this phase of supervision.

Records

An inspector's coupon, shown in Fig. 5, is made out by the inspection department. It shows the number of units completed daily in each group, and the quantity OK'ed and rejected; and is turned into the time-keeping office not later than 8:00 a. m. the following day. From this inspector's coupon the time-keeping department makes up a group piece-work report showing all of the employes in the group, the number of hours worked and the amount earned according to their hourly day-rates; it is illustrated in Fig. 6. The report is made in quadruplicate; the first copy goes to the pay-roll department, the second to the time-study department, the third to the foreman of the department and the fourth copy is retained by the time-keeping department. The foreman of each department is enabled to know before 10:00 a. m. each day just what each individual's earnings were for the previous day. This feature of the group system is highly favored by the employes.

Some of our employes have worked on group systems in other plants, and could not be informed what their earnings were until the end of the pay-period. The ability to inform the employe on a given day what his earnings were on the previous day is one of the reasons the method described is favored by both the company I represent and its employes. If an employe quits or is discharged, we can calculate his pay from the number of units finished at any hour of the day, inasmuch as we know how many units have been completed up to that time.

The only time-card used is an in-and-out card showing the employe's attendance. The time-cards are stamped by the time-keeping department, indicating the


GROUP PIECE WORK REPORT

NAME OF GROUP OR PART Cylinder Blocks PART NO 651 GROUP NO 102 DATE 10-1-23

Fig. 6—Group Piece-Work Report

group number to which the workman is assigned; the employe merely rings "in" and "out" upon entering and leaving the factory.

Group Size

The question often arises as to the proper size of a group. We have found that the group should be limited to the unit itself. There should be not more than one group on any one unit. We have in operation one group of 92 men, and one group of 83 men; the smaller groups run as low as 3 men. Other groups are of 10, 15 and 20 men. Each group of men completes one unit. By having the group gaged according to the unit, there is no tendency for any of the prices or for production to be out of balance. For example, if two groups were engaged in one unit, one group might be short 2 or 3 men and not be able to furnish the second group with enough units to keep its men busy; the latter would be limited to what the first group produced; but, by having all in one group, the production would be balanced to suit the number of men engaged. There is a limit perhaps to the size of a group, but we have yet to find what the high limit is.

Material Supply and Costs

Whenever parts needed by a group-unit are required for service, the service department issues a requisition in duplicate, one copy of which goes to the time-keeping department as a check against the number of pieces withdrawn. For example, the service department may require 100 valve-lifter assemblies. The engine-assembly group assembles the valve lifters that are paid for at a certain price per piece, and the total earnings from these service parts assembled are added to the group earnings and prorated among the entire group. All piece prices covering service parts are established from the time studies made on the component parts of the group when the group unit is originally timed. Thus, with a flat price on any group, the management, the cost department and the employes know at all times what the price per unit is. There are no bonus nor premium calculations which in any way vary the costs.

Any increase in workmen's hourly-rates does not affect the cost, and the one thing that the employer wants to know with certainty at all times is just what the direct labor cost is. A definite understanding is had between the employer and the employes as to the amount of work to be produced for the compensation to be received. Failure of some systems to accomplish this has been the principal reason for objections to other wage-incentive plans. Some of these systems are so complicated that the employe cannot understand them or figure his own wages; it is also necessary for the cost department to maintain a large clerical force to keep the proper records needed to secure costs. The costs so obtained are subject to fluctuations, and it is necessary to compile them for a period of from 6 to 12 months to obtain an average cost. It seems, then, that the ideal system is one which can be "sold" to the employer and the employe as well, and will tell at all times the definite work to be done and what the compensation therefor shall be. It appears that many systems that have been devised have been wholly lacking in this respect.

Our company and its employes feel that the group piece-work and the straight piece-work methods now in operation in our plant have met all of the principal objections generally experienced with other wage-incentive systems, and think that this system is satisfactory in every way.

AUTOMOBILE INTERIORS MORE COMFORTABLE

ATTENTION has been called previously to a simple means for decreasing the heat radiated through a tent or other light covering that is exposed to the sun. By coating the underside of the tent cloth with aluminum paint, the heat radiated from the underside is reduced by 86 per cent. Painting the outside with aluminum paint was found to be slightly less efficient, the heat radiated from the underside being reduced only about 80 per cent.

Coverings of conveyances, such as, for example, the tops of automobiles, ice wagons, etc., consist of cloth, the outside of which is often painted with a black composition that absorbs perhaps 90 per cent of the sun's rays. Practically half of this is radiated from the underside of the cloth. Tests are in progress at the Bureau of Standards which show that a coating of aluminum paint applied either to the outside or inside of such tops reduces by 50 to 60 per cent the intensity of the heat radiated from the underside into the interior.—Bureau of Standards Technical News Bulletin.

Cooperation in the Solution of Service Problems[1]

By B. B. Bachman[2]

DURING the last quarter of a century, which covers the inception and growth of the automotive industry, there have been many and remarkable changes in the world of commerce. This period covers the time when intense agitation against the accumulation of financial and industrial power in the hands of a few individuals brought out the fact that a successful business compatible with the public welfare must not only be law-abiding but also possess a high sense of responsibility and that quality which we call character.

In the beginning of our industry, founded as it was on the invention of a new device, the individual occupied a most conspicuous place. This was a phase that passed rapidly, but during this period and for some time thereafter we saw this individualism strongly emphasized. Sales appeal was first based on novelty and the sporting instinct as it reacted to the speed possibilities; following this, the matter of luxury of appearance and appointment, and, finally, the question of transportation facility.

With this change in perspective and the continually broadening market opened up by the reduction in price made possible by an increasing volume of production, the importance of the individual and of the efforts of inventive genius as evidenced by distinctive mechanical details, has given place to the collective efforts of an organization in developing the automobile and fitting it into the fabric of our national life as the principal means of individual transportation. This development in design and the methods of production are not sufficient in themselves, however, to make it possible for the automobile to give a satisfactory performance in this field.

It seems to be fundamentally sound to anticipate that a piece of mechanism as complicated as an automobile, even if placed in the hands of the most expert operator but subjected to the variables of climate and road condition to which it is generally exposed, would, even if initially perfect in design and in the selection of materials and in the manufacture and assembly of component parts, be subject to wear and depreciation which sometime or other during the life of the product would require attention in the way of adjustment, repair or renewal of parts, which could only be taken care of properly in adequately equipped shops, manned by a trained and intelligent organization. It seems to be equally obvious to assume that the provision of such facilities constitutes an element in the business of building and selling automobiles which can not only perform its functions to the enhancement of the reputation of the product which it serves, but also accomplish this result on a profitable basis.

If under the ideal conditions outlined in the foregoing, we consider the case for a service organization, it is at once apparent that a departure from the ideal state by the introduction of other complicating factors such as inexpert operation, variations in design, shortcomings in manufacture in both materials and parts, to mention but a few, makes it absolutely essential that any product, to be successful in the hands of the user, must have these service facilities.

Conditions of Manufacture

It is probably too much to expect that a vehicle as it leaves the factory finds itself so perfect and that no variables of performance or construction would be present. In the case of the presence of these variables it is, of course, not to be supposed that the purchaser should be penalized by having to bear the burden of the results of these shortcomings. On the other hand, it is possible that a moderate expenditure on the part of a selling organization in the way of free service may be a legitimate form of advertising, especially in new territories, or with particularly unskilled operators.

It is, of course, self-evident that the facilities mentioned cannot of themselves insure satisfactory service or that minimum of maintenance expense which is rapidly becoming essential. The designer cannot content himself with creating a cleancut, neat design with proper factors of safety in materials and adequate bearing surfaces and facilities for lubrication if the components are so related to each other that the machine can be repaired only with an unwarranted expenditure of labor and the use of special tools and equipment. He must recognize that there are certain things which will happen, making repair and adjustment necessary, and must provide in the design that this can be done easily and economically, just as he knows there are certain things which must not fail except under the most extreme circumstances.

In laying down a design for a vehicle, there are a number of limiting factors which must be taken into consideration. Some of these are of a commercial nature, such as the market to be reached and the price-level to be established. Some of them are of a technical nature, such as the power and performance expected and the strength and endurance to be built into the design. Others have to do with production, such as the character of the parts in relation to the equipment and the plant available. Some of them have to do with operation and service, such as the number and the complexity of the parts and the accessibility for repair and adjustment.

This classification is not definite, for the reason that these requirements overlap, some of them having to be considered from several angles. It is obvious that a 100-per cent solution of the problem, taking into consideration all of these factors, is difficult, if not impossible. The result will therefore be a compromise in which some of these details have been given preference over others.

In most organizations the influence of their commercial, sales and production divisions are closer to the designer than is the service end, with the result that more attention is paid to ease and economy of construction and to appearance than to the equally important matter of accessibility and simplicity in maintenance. I believe that one reason why this is so is that there has not been the unified opinion from the service department as a result of cooperative activity that there has been from the other divisions.

Elements of Service Facilities

Accordingly, we can say that the interest of the manufacturer in the establishment and maintenance of adequate service facilities lies in three directions: first, that his product shall be placed in the hands of the prospective user with such instructions as are essential to insure its being operated in a correct manner; second, that along with the facilities for selling the product there shall be adjacent to each user an organization and equipment competent to remedy such defects in design and construction as may exist and for which he is responsible, and facilities for the supply of corresponding renewal parts, and for the performance of such repair work as will be necessary due to normal depreciation from usage; third, an organization which on account of its competence and familiarity with the product can report the

nature and scope of difficulties that develop in service, due to either defective construction or normal usage, together with a criticism of the design from the viewpoint of accessibility, for the purpose of permitting intelligent and constant development and improvement of the product.

It may seem that the valuable aid which the service organization can render to the selling and manufacturing departments would be an asset in which it would be a desirable thing for an individual company to excel to the point where no one else could compete. Such a conception would require guarding the methods and the processes in use with the greatest secrecy. The growth of the industry in the past and its potential growth in the future make it evident that no individual organization can possibly control this factor or supply the facilities that should be available to provide adequately for even its own product.

As the automotive industry grows and as competition becomes keener, as the general public becomes more automobile-wise, the question of the cost of maintaining the equipment in operation will bear a larger and larger significance. The United States is the only country that, up to this time, has adopted the automobile as an everyday, all-the-year round, continuous means of transportation. One reason for this is that we have, in view of the character of design and our methods of production, been able to place vehicles in the hands of the public at prices that came within the reach of everyone, irrespective of social or financial conditions.

The matter of the oft-discussed topic of the saturation point of the automobile market bears no significance in my mind, except insofar as we are unable to find practical means for keeping the cost of operation down to reasonable figures. How to do this has no part as a subject in my discussion, but is a subject with which the service-man and the service organization are most intimately and vitally concerned, and the sooner the service people can get together and discuss this problem from all its manifold angles and present the subject, analyzed and in detail, to the sales, production and engineering departments of the organizations with which they are connected, the sooner will we begin to make real progress along this line. It is probably unnecessary to point out that considerable progress can be made and, as stated before, is absolutely essential.

Increased Cooperation Needed

The spirit of the times is for increased cooperation in the development of matters of this sort that will move forward the individual with the industry. This cooperation does not mean the elimination of rational competition but it does mean the elimination of unreasoning antipathy to associating and exchanging experience on a cooperative basis with others in the same line of endeavor. It is not so many years ago that the automobile industry was composed of a group of units, each individual being suspicious of the methods and ideals of its competitors. Our factories were locked up, and particularly our experimental and engineering departments were kept guarded in a most jealous manner.

The contact between and the association of manufacturers that has been developed in the National Automobile Chamber of Commerce, growing out of the Association of Licensed Automobile Manufacturers, and the interchange of ideas and the expansion of knowledge which have resulted from the growth of the Society of Automotive Engineers, successor to the old mechanical branch of the Association of Licensed Automobile Manufacturers, have been in harmony with the increase in cooperation in all lines of endeavor. The results have indicated how much is to be gained by this form of association and interchange of ideas.

The Society of Automotive Engineers has recognized for some time that in the automotive field, as in that of the railroad, there will eventually be many more engineers occupied with the operation of vehicles than with their design and construction, and that to become a truly representative organization for the engineering fraternity of the automotive field it will be necessary to widen its field of operations and the scope of its programs to provide for this large and rapidly growing class of men. Therefore, within the last several years there have been held at Chicago, in connection with the National Automobile Show, meetings of the Society devoted to the subject of service. While the attendance at these meetings has been fair, it has not come up to the full possibilities. We are prepared to admit that the programs which have been selected may not have carried the fullest appeal to the service-men. At the same time, it is fair to state that it has been exceedingly difficult to get competent service-men into the frame of mind where they would open up and present their views. Possibly the service-men as a class have not advanced very far from the status of mere repair-men and have not obtained the broad view of the necessities and possibilities in their field. I am not criticizing but merely endeavoring to point out the need for a broader viewpoint, to be obtained only by mixing and thinking in more fundamental terms.

Engineering Fields

There are two general fields in the automobile industry in which the engineer has an opportunity to use his talents. These are constituted of many subdivisions with which I will not attempt to deal. One field is that of construction, incorporating the subdivisions of research, design, development and production. The second is the field of operation, embracing the subdivisions of service and application. You will understand readily that the first engineering talent which came to notice in the industry was that which designed the vehicle. No ingenuity could be exercised in constructing and servicing vehicles until the designs had been created. We can all recall the advertisements of earlier days in which the names of famous designers were placed before the public as sufficient reason for their purchasing.

Following this creative period, we came to the time of rapidly expanding production. It is only natural that, with an eager public apparently able to absorb an almost unlimited output, the problems of service should have received relatively less attention than those of production. I believe that this condition has changed, and that we are entering into a third period in which the question of properly selling the product and of keeping it sold is involved.

It is of fundamental importance to the growth of the industry that professional jealousy or antipathy between the various divisions mentioned should be eliminated and that in their stead there should come the most complete harmony and cooperation. It is manifestly impossible for any but the most exceptional man to become expert in all these various lines. It is equally certain that expert advice from all of these fields is necessary to develop the automotive vehicle satisfactorily. It is therefore essential to attaining this end that organizations exist in which the members of the different groups can cooperate and interchange experiences with their fellows in the same group and in the entire field.

To do this, as I have suggested before, requires a broader vision of the subject than is possible for the ordinary man to obtain in his own limited sphere of activities. The value of service to the industry and the importance of the service-man are such that he should not be content to drift along with the times, but should take active steps to place his part of the industry and himself on a par with all of the other divisions and individuals.

I believe that the only way that this can be done is by effective cooperation. The formation of local service organizations is an excellent and effective method of accomplishing this in a very large degree. There are, however, many phases in the business of service and each has its own problems as well as common ones. As an engineer, I naturally see the engineering side most clearly, and therefore in addition to this form of general organization, I believe that the service engineer should avail himself of every opportunity for association with his fellows in the industry.

It is in this field that I believe the Society of Automotive Engineers can be of assistance. The constitution of the Society, in citing qualifications for membership, recognizes the standing of the competent engineer in the service field, as well as in the production and designing fields. For the service engineer to analyze his problems correctly, he must

(3) We have not these facilities in the necessary quantity and quality today

(4) The business of furnishing service in this field of transportation can be made profitable if conducted properly

(5) To conduct it properly, and thereby profitably, much must be learned and many problems solved

(6) In learning the requirements and solving these problems, cooperative endeavor in helping the weak to become strong will help the strong to become stronger

SIMPLIFICATION

JUST as the manufacture of goods on a large scale reduces their cost and hence permits price reductions that augment the sales volume, and the increased sales volume thus attained again conduces to yet lower manufacturing costs, so do the various operating advantages of simplification react at successive levels to augment and multiply one another. Suppose, for example, simplification takes place in the variety of the product manufactured. The elimination of certain items from the line and concentration upon others then cause longer machine-runs and a lowering of unit overhead costs, both through continued utilization of the equipment and through the avoidance of setting-up expense. But automatically, the standard practice that brings about such savings in production results in other savings outside the operating departments. Stores, accounting and planning departments are inevitably affected; regular repetitive production entails less expense in the way of record-keeping and the maintenance of various control devices in auxiliary departments.

Better control of materials, simpler accounting methods and more timely planning and scheduling then result in stabilized operation; which further conduces to lowered costs, better quality product, smaller inventories, shipment that is prompter and delivery that is more dependable. The latter advantages then again result in yet larger sales. Buying in larger quantities obtains still more favorable concessions from sellers. Steady and continuous operation relieves labor turnover and gives the management its pick of both skilled and unskilled labor.

It is the sum total of all of these cumulative, interrelated effects which counts. In many cases, the saving in any one department may be small when considered by itself, but the effect that it will have upon the other departments and the savings of the second and third departments in relation to those effects, often great, can be very large indeed when taken together. The stabilization of all business operations permits a better control over costs. A knowledge of costs permits control over sales policies. Control over sales permits a ready coordination with production, and the coordination of production and sales results in the general stabilization of employment, permitting promotional and financing operations. This, cumulatively, the workings of each step in simplification affect the operation of the entire enterprise.

Very generally, at its pioneer stage each commodity runs the gamut of various types and patterns, shapes and sizes, in selling items adjusted to the purpose and market. After these are established, however, useless differentiations tend to persist. As we swing into each new field of production, that field, for the time being, gives play to the human desire for ostentation, variety and luxury; but as time goes on those desires center themselves in new devices and commodities, leaving behind a number of types and varieties of product that ordinary economic processes only slowly, if ever, eliminate.

This development is paralleled by a needless complexity and indirection in production methods, marketing practices and the general minutiæ of control. Unnecessary motions become embedded all along the routine of making and selling. A possibility for a dual combing process results and in this lies the opportunity for real simplification. To obtain an increased output from fields already being worked and to free our productivity for enterprises in new fields a conscious overhauling is repeatedly required at certain stated intervals.

On the one hand those types and varieties that have been demonstrated to be ineffective should be weeded out as rapidly as possible. Once the pioneer stage in the production of any variety or type of a commodity is past, it should be subjected to a scrutinizing survey, rather than to wait on the slow processes of natural elimination. On the other hand, all unnecessary practices in connection with manufacture and sale, in purchasing, in fabrication or processing, in storage, in shipments and deliveries, even in finance and accounting, should be discountenanced with equal vigor. As the conditions of trade or manufacture change, scrutiny should be repeated to detect again any unnecessary motions. Finally, all new steps proposed should be carefully examined and critically challenged in the light of whatever added complexity to operations or processes they may entail.

So far as diversity of products may be involved, simplification is not hostile to any styles or varieties of product that appeal to the public fancy. It aims, first, only at eliminating those varieties and types that do not serve even a semi-frivolous purpose; and it aims, also, at giving to the non-frivolous elements in the population a chance to purchase articles of sound utility at minimum prices. And, secondly, by eliminating all unnecessary steps and practices in the productive, distributive and facilitative activities of each plant or store, simplification aims, further, at giving to the entire community an increased volume of goods and services and a higher standard of living.—A. W. Shaw in *Harvard Business Review*.

Developments in Production Grinding in the Automotive Industry

By Oscar A. Knight[1]

Production Meeting Paper *Illustrated with* Photographs and Drawings

IN production grinding the progress made during the past few years has been along the line of grinding multiple parts simultaneously, such as piston-rings, ball and roller-bearing cups and so forth. This kind of grinding brought about the use of wider wheels to cover the entire surface of the work whereas formerly narrow wheels had been used with the traversing table method. With the development of these operations came the cylindrical grinding of square and distributor cams; also square shafts, using the oscillating cam grinding attachments; piston relief grinding with the same attachments; and two-wheel or double-wheel grinding for such parts as steering-knuckles and pinion shafts of different diameters or where two diameters are separated by some protrusion, as in steering-gear worm-shafts.

To accomplish these new operations more care has been taken to build machines that are heavier, stronger and more accurate so that operators can place greater dependence upon the mechanisms than was possible with previous machines. Greater care has been taken to balance the grinding wheels more accurately to overcome imperfections in finish and to eliminate excessive repairs on the grinding machine itself. Some of the new attachments, mechanisms and grinding machines are described in detail in the paper.

In conclusion the author states that the automotive industry has become the chief element in machine-tool business in the Country at the present moment and therefore the principal factor in forcing new developments in machine-tool design. He also points out the importance of a quality product to serve the needs of the automotive industry adequately.

[1] Detroit district manager, Norton Co., Worcester, Mass.

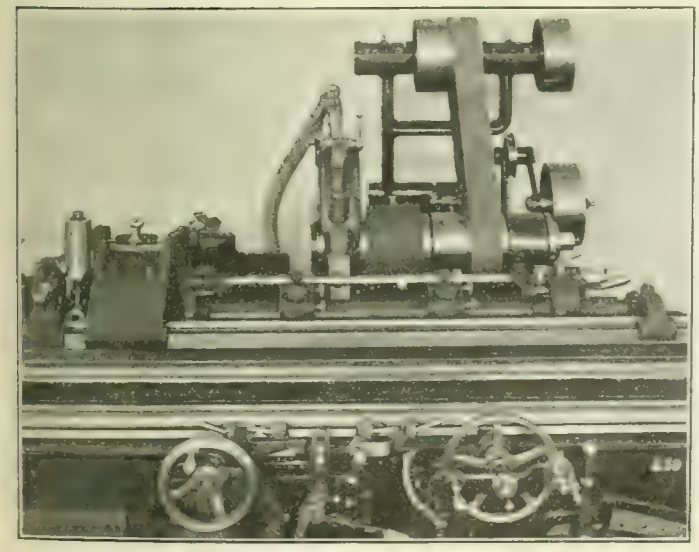


Fig. 1—Grinding a Camshaft

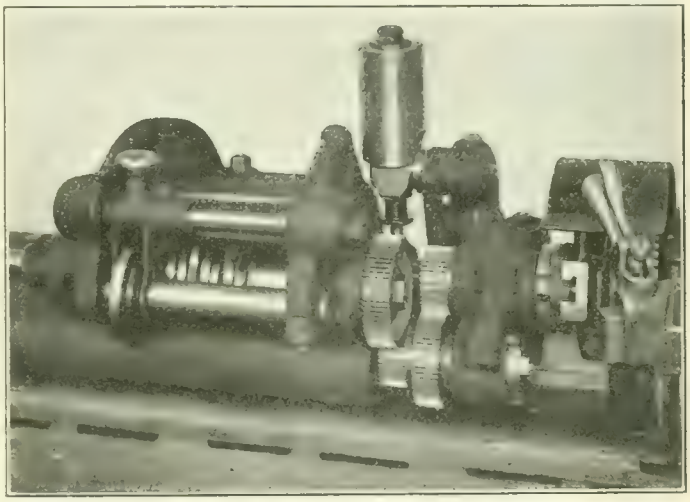
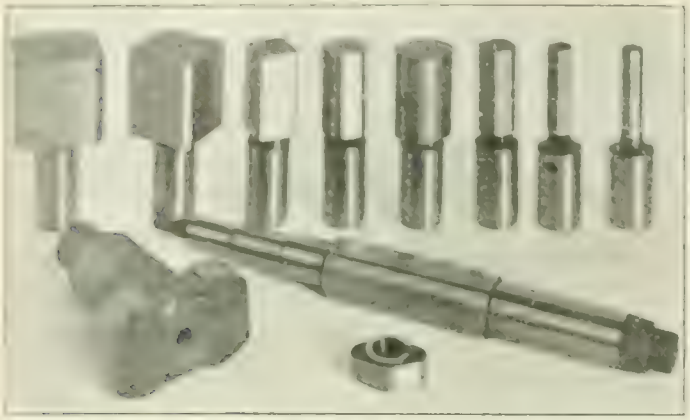


Fig. 2—Attachment for Grinding Cams

ADVANCEMENT and development in any art or science is brought about by necessity, and the developments in precision grinding in the automotive industry have been accomplished to meet the demands for greater production and refinement at less cost. To cover the developments that have been made in all classes of production grinding would consume too much time. Therefore, I will deal with only one class, namely, cylindrical production grinding as performed within the automotive industry, with only a slight reference to other classes. Production grinding should also be classified as *precision* grinding because to secure the largest production of good ground-work the exact limits required for size and finish must be considered. Webster defines "precision" as "exact limitation, strict conformity to a rule or standard." This means that modern precision production grinding is always performed within exact limitation to some given rule or standard.

The progress made in production grinding during the past few years has been along the line of multiple-work grinding on such parts as piston-rings and roller- and ball-bearing cups. It brought about the use of much wider grinding-wheels to cover the entire surface of work that had formerly been ground with narrow wheels by the traversing table method. Along with the development of these operations came the cylindrical grinding of square and distributer cams; also square shafts, using oscillating cam-grinding attachments; piston relief grinding, with the same attachments; and two-wheel or double-wheel grinding for such parts as steering-knuckles and pinion shafts of different diameters or where two diameters are separated by some protrusion as in steering-gear worm-shafts.



To perform these new operations more care has been taken to build machines that are stronger, heavier and more accurate so that operators can place greater demands upon the operating mechanism than was possible with previous machines. Greater care has to be taken to balance the grinding wheels more accurately to overcome imperfections in finish and to eliminate excessive repairs on the grinding machine itself. At the same time, grinding-machine builders have devised means for bringing back into approximate running-balance wheels that have developed vibrations as they have worn smaller in their use.

New machines and special attachments have been put into use recently and the accompanying illustrations show some of the developments that have been made in production grinding in the automotive industry. It is unfortunate that some of the very best examples of real progress could not be photographed for inclusion in the paper.

Cam Grinding

In the early days of the industry cams were made individually and pressed over a staight shaft and located in their respective positions by a Woodruff key. The attachment which ground these individual cams according to the shape required, oscillated in its movement. The shape was reproduced from a master cam contained within a case that formed part of the attachment.

Engineering progress caused a change in this part and whole camshafts with all cams forged in place were given to the grinding engineers. One of these shafts mounted in the grinding machine is shown in Fig. 1.

To meet this situation the integral cam-grinding attachment, which could be placed on the table of machines already being manufactured for other classes of grinding, was produced, and all the cams on a shaft were ground from the forging to the finished dimensions. This attachment, which is illustrated in Fig. 2, also oscillates in its movements and grinds to very close limits of accuracy all cams from 2 to as many as 24 on a single shaft, in accordance with the generated shape of the master cams.

Since this device was developed very little change has been made in its form but its accuracy, alignment and rigidity have been greatly improved so that today a whole camshaft having 12 individual cams integral with it is ground in about the same time as one individual cam by the original method.

Most automobile pistons are relieved around the wrist-pin hole, while a few makers desire an elliptically shaped piston to allow for heat expansion. This is accomplished with a loose cam or similar form of oscillating attachment. The relief or elliptical shape is reproduced from a master cam within the case at the side of the driving mechanism. By this method reliefs are ground in pistons at the rate of from 125 to 175 pistons per hr., while from 40 to 75 pistons that are elliptical throughout their entire length are produced per hour, depending upon their requirements for accuracy and finish.

Square and other shapes having a flat surface with connecting arcs and radii as shown in Fig. 3 are now ground in attachments similar to that used for relieving pistons, as well as the attachment for automobile cams illustrated in Fig. 2.

With this method a square end on a transmission shaft measuring 1 in. square and 3 in. long can be ground at the rate of 65 pieces per hr., removing 0.020 in. of stock from the diameter to within a total limit of 0.001 in. for

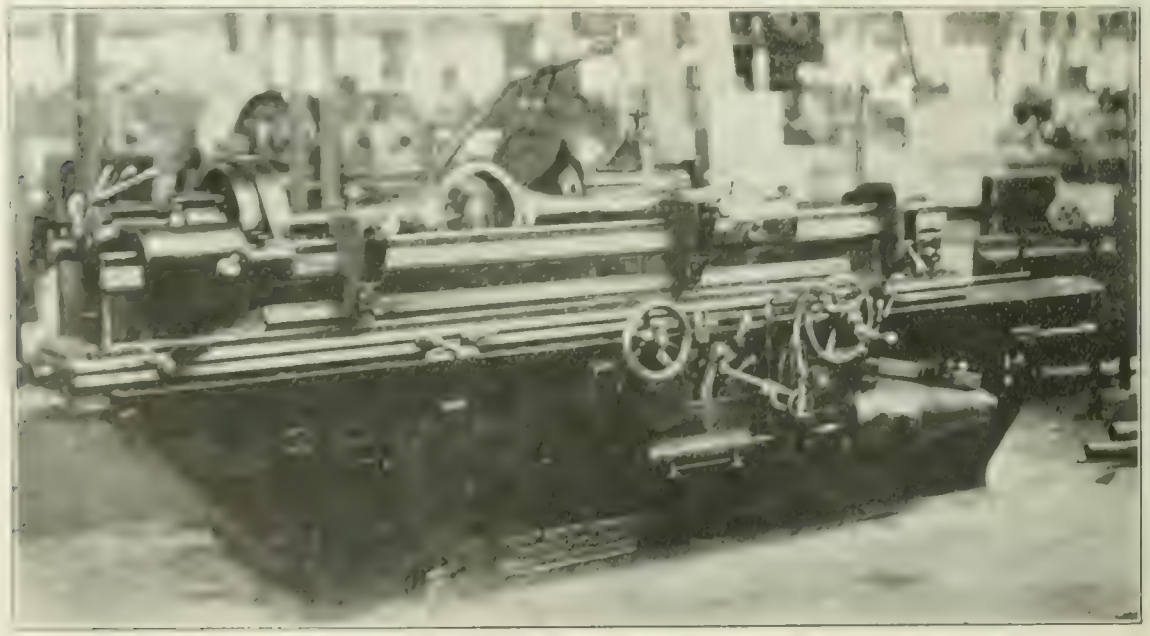


Fig. 1—Rear Axle Housing Having a Long Straight Bearing on Each End

square, diameter and flat on all surfaces, the limit on the flat surfaces being from flat to 0.001 in. concave. This is a 90-per cent increase in production over the old method when using cup wheels and a hand-operated indexing mechanism. Many automobile companies have adopted this new method for grinding squares on transmission and pinion shafts, as well as brake cams for their rear axles.

Use of the Wide-Face Wheel

The principal development in production grinding during the last few years can be attributed directly to the application of the wide-face grinding-wheel in its many phases. The automotive industry is largely responsible for its introduction and advancement. This method was used widely during the early stages of the World War for form-grinding shrapnel and other shells.

One of the best and most profitable examples is shown in Fig. 4. This is a common rear-axle housing with a long straight bearing on each end, which requires not so much a reflective finish as it does a round and straight bearing. To accomplish the work satisfactorily a new steadyrest has been employed which has overcome many difficulties encountered in holding this class of work round, as well as made it easier to grind heavy and out-of-balance pieces more accurately.

The feature of this rest that distinguishes it from the rest formerly used is the independent control of the horizontal and vertical motions of the work-shoes. The previous rests were fitted with one shoe that had to be discarded when the fixed arc had worn oversize. With independent motions of the work-shoes, as in this rest, the shoes give much longer service by virtue of a generous allowance for wear provided by their adjustability.

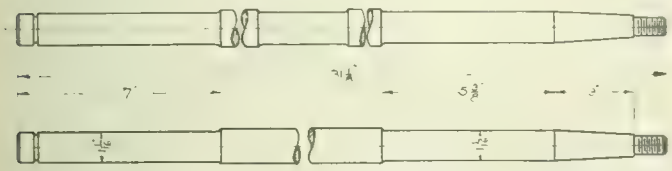


Fig. 5—Two Drawings of a Rear Axle That Is Finished by Grinding

In the Earlier Type Shown in the Upper Drawing a Flat Spot at the Center Served as a Steady-Rest While the Ends Were Ground with a Narrow Wheel. The Lower Drawing Shows the Form Now Used and Ground with a Wide-Face Wheel

Housings such as that shown are now being ground on each end by the full-width wheel method at the rate of 20 and 21 pieces per hr., removing 1/16 in. of stock to limits of 0.0010 in. for diameter and 0.0005 in. for roundness. This is done without any previous turning or snagging operation whatsoever.

Another good example of the parts produced with a wide-face wheel is the rear-axle shaft illustrated in Fig. 5. The upper drawing shows an axle with a middle spot used in the old days as a steadyrest spot to prevent vibration while the narrow wheel ground each end. Production was 12 ends per hr.

The application of the wide-face wheel removed the necessity for the spotting operation as shown in the lower drawing and increased the production obtained in 1913 to 46 ends per hr. Today on the same axle with the introduction of newer types of heavier machine, with the two-bearing independent-shoe type steadyrest, the production has reached 800 to 1000 ends in every 8-hr. shift, which is an average of 100 to 125 ends per hr. These two examples of wide-wheel grinding are sufficient to show the advantages when applied to work not wider than 9¾ in. on the ground portion.

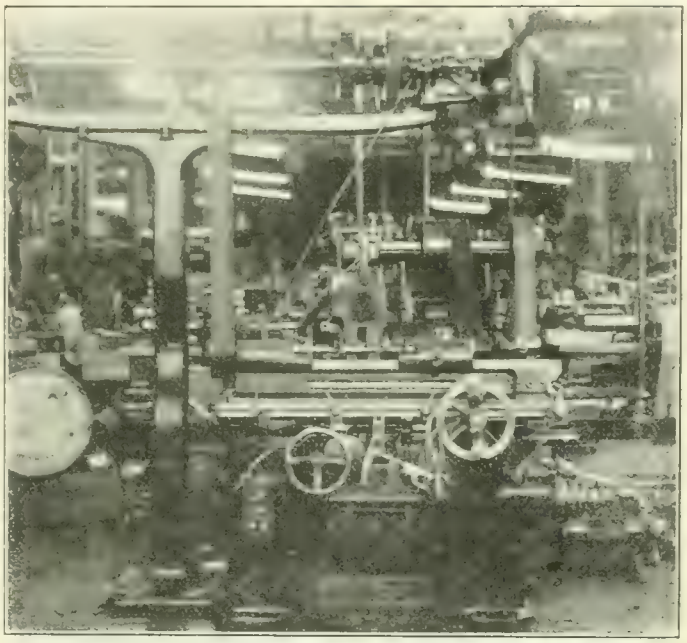


Fig. 6—Grinding a Steering-Knuckle

Special Attachments

During the last year a device known as the wheel-spindle reciprocating attachment has been developed and supplied to automotive plants. When using the wide-wheel method of grinding, before the development of this attachment, it was necessary for operators to move the work-table backward and forward by hand to break-up the grain lines in the work. This movement of the work across the wheel also served to keep the cutting-face wearing evenly. Both of these functions are now performed by this attachment, the use of which has decreased the number of truings required and the manual labor on the part of operators, increased the production and improved the quality of finish.

Great interest has been shown in the grinding of several diameters at one draw-in or straight-in cut, using two or more wheels mounted on a single wheel-sleeve.

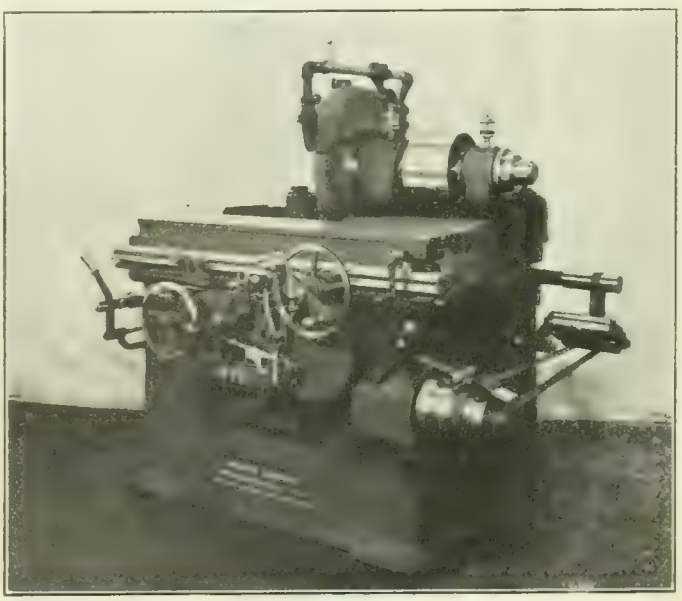
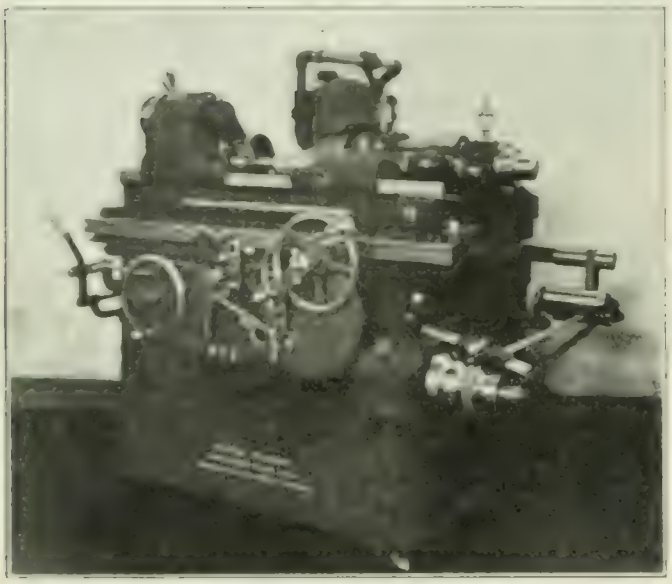


Fig. 7—A Recently Developed Flat-Table Machine Having a Swivel Table

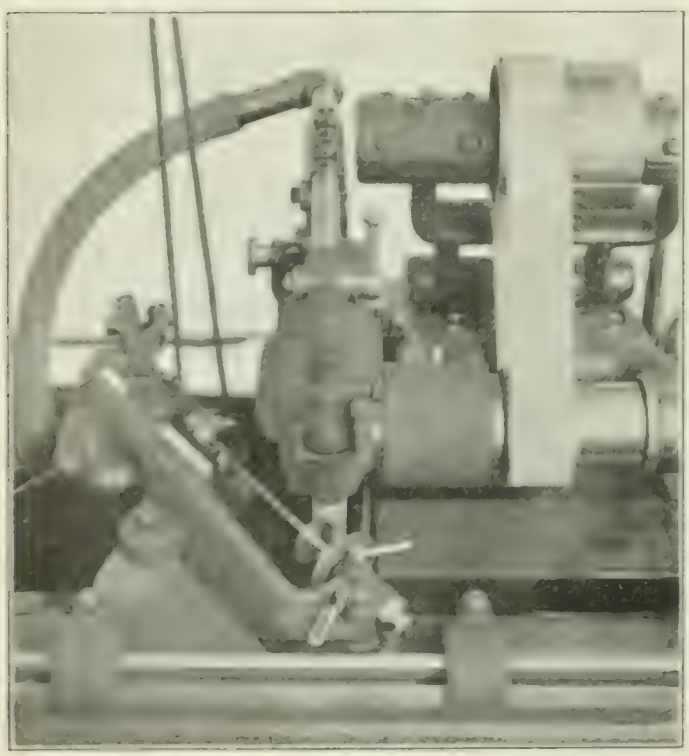
Wade as shown the machine is prepared to grind such work as steering knuckles, pinion shafts, some transmission shafts, small differential-case bearings and such work where protrusions separate two or more short diameters.

Fig. 6 is reproduced from an actual photograph of steering-knuckle work being performed in one of the large automobile-axle plants. In the former days when



[illegible]

one diameter was ground at a time, the hourly production was 50 complete knuckles. By the application of this new double-wheel method the production has been increased to 95 complete knuckles per hr. To accomplish this a special truing-ring with positive stops has been applied to the wheel-feed gear and each stop set for



[illegible]

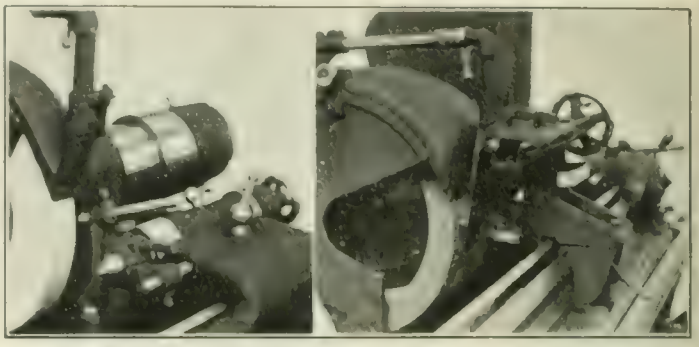


Fig. 10—At the Left a Radial Wheel Truing Attachment and at the Right a Wheel Forming Device

truing its own wheel. When both are trued to their respective diameters, a third stop is used as a positive infeed locator for exact sizing. Many automotive plants have adopted this method of double-wheel grinding for work where this method is effective.

Grinding-machine companies have designed and built their machines with special-shaped tables, believing that in their respective particular shapes were to be found great advantages of rigidity and of retaining the correct alignment between the centers of the headstocks and

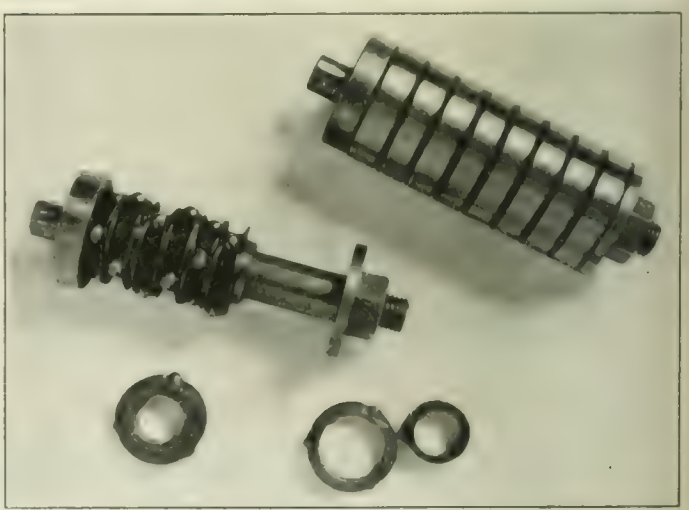


Fig. 11—A Special Arbor for Grinding the Rings of Ball and Roller Bearings

footstocks. This made it difficult for them to design suitable special fixtures for special grinding jobs.

In the last year flat-table machines have been developed that consist of a swivel table made to a height to accommodate a user's special requirements. One of these machines is illustrated in Fig. 7. During the same period the grinding-machine builders have been requested to produce certain other special attachments to enable their customers to secure a larger production of certain kinds of work that can be finished best by grinding. One of these special attachments is an adjustable speed live-spindle headstock that is used for grinding such work as pistons and other open-end pieces and differential cross-members. When grinding pistons on this attachment as shown in Fig. 8 the face-plate is removed and a special cone driver screwed into its place. The pistons are then ground at the rate of 75 to 90 pistons per hr., depending upon the degree of accuracy and finish required.

The attachment illustrated in Fig. 9 was developed for attachment to regular machines for grinding seats on

valves. Adjustments for the length of the stem as well as the degree of taper on the seat are provided. A special feature of the attachment is the provision that has been made for grinding on centers, although other attachments of this same form are fitted with collets to grip the valve-stems.

Many of the makers of crankshafts have insisted upon very accurate round fillets at the ends of crankpins and bearings. A device for forming a radius on the grinding wheel and also for truing the face of the same wheel is shown at the left of Fig. 10.

Certain jobs having a taper and several straight diameters can be ground best with the wide-face wheel. The

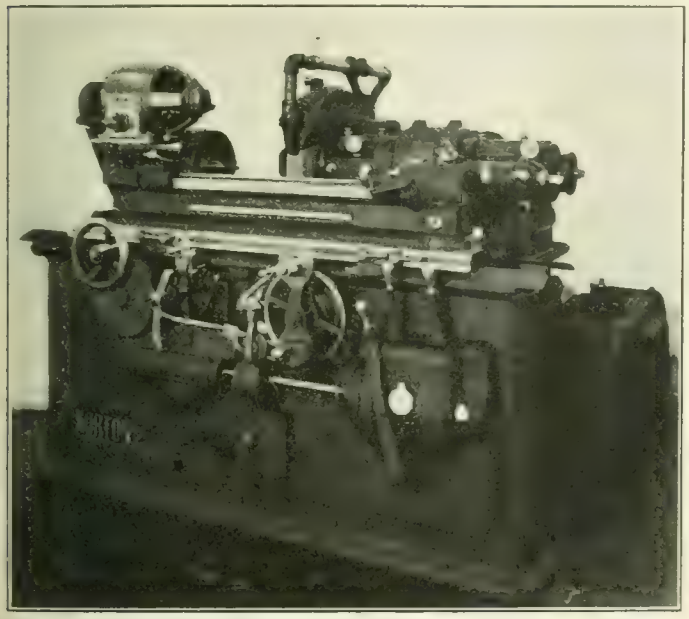


Fig. 12—A Self-Contained Type of Grinding Machine Equipped with a Power Table Traverse for Handling Oil-Tubes, Rocker-Arm Shafts and Similar Work

forming device illustrated at the right of Fig. 10 has been developed to form the wheel for grinding an entire surface, including tapers or straight portions. The form of the wheel face is generated from a form-bar that is located directly in back of the roller. The operator places the attachment on the table in front of the wheel

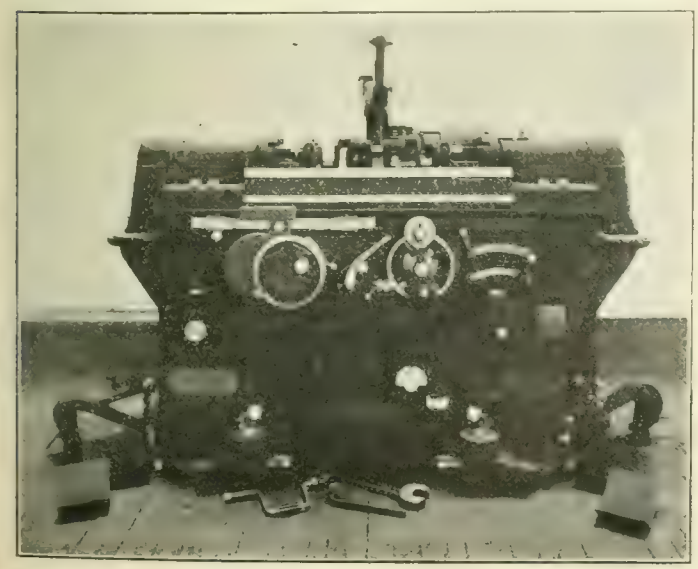


Fig. 13—Crankpin Grinding Machine

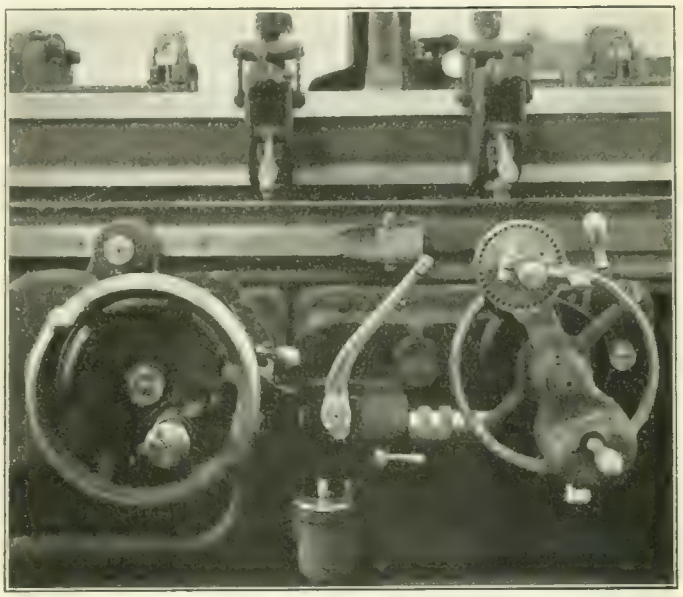


Fig. 14—The Automatic Wheel In-Feed Mechanism of the Machine Illustrated in Fig. 13

which is brought into contact with the diamond. He then turns the handwheel, moving the diamond across the face of the wheel, following the outline of the form-bar and reproducing it on the wheel face. Since the introduction of this device the production has been increased from 100 to 400 per cent in a great many instances.

In ball- and roller-bearing work special arbors of the type shown in Fig. 11 have been made for holding as

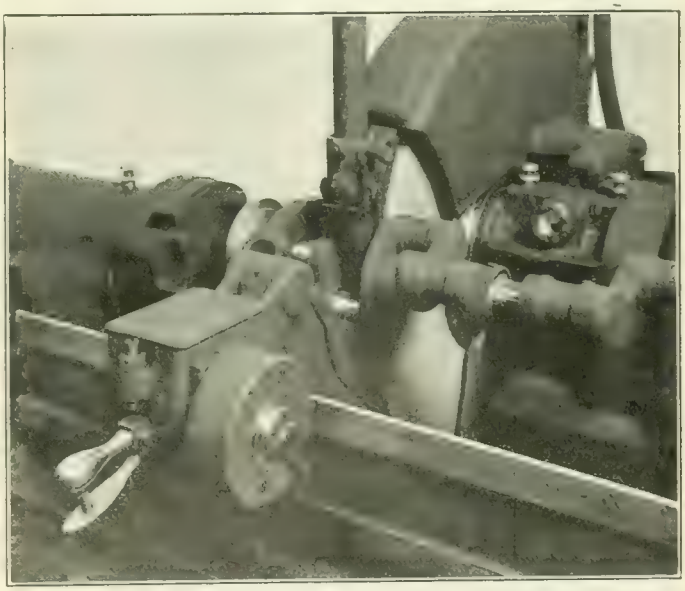


Fig. 15—The Automatic Steady-Rest Used on the Crankpin Grinding Machine

many rings as can be covered by the wide-face wheel, not over 10 in. wide. By this method production has been increased from 100 to 400 per cent over what was formerly attained with narrow wheels. In addition to this the wheel-spindle reciprocating device has been applied to the machine. This addition improves the quality of the work, increases the production and reduces the wheel cost.

Special Machines

For several years the automobile companies have made a careful study of machine maintenance and have said

[illegible] machine was very expensive to operate. Now the demand has changed and requests have been made for machines having self-contained drives and controls. The grinding-machine industry has brought out new types of machine with this thought in mind and also with the purpose of still greater production of good work at less maintenance cost. Fig. 13 shows the most newest self-contained development, which is arranged for power table-traverse drive for such work as roll-necks or rocker-arm shafts having a larger ground diameter than could be covered by a wide wheel.

Another special-purpose machine has been developed in which the grinding is done on the extreme right end for such work as axles, drive-shafts, pinion shafts, sleeves and other parts where the wide wheel is the most productive. For all short work a short, stiff, compact machine equipped with the wheel-spindle reciprocating attachment and the power in-feed attachment that is used for automatic straight-in feed of the wide-face wheel that covers the entire surface of the part being ground has been brought out.

All of these new-type heavier machines are equipped with new mechanisms for driving the wheel. The wheel spindle is driven by a belt from the power shaft, enclosed in the base, and running in self-oiling ball-bearings. The wheel-spindle bearings are of a new and improved type and are lubricated by a constant stream of oil, forced through the bearings by a pump. Their adjustment is so simple that the operator can overcome all looseness by simply turning the thumb-screws while the spindle is running.

I have mentioned these features because it is through these new and improved designs on the part of the grinding-machine builders that larger production and improved quality have been brought about.

Crankshaft Grinding Machines

Ever since the very beginning of automobile-engine building, the crankshaft has been a most difficult part to machine. The last operation has been the grinding of the crankpins and the great difficulty has been to finish these pins round and straight to within small limits of accuracy, practically free from any imperfection. Considerable difficulty has been experienced in obtaining the required accuracy, and it is remarkable how successful the makers of crankshafts have been with the machines given to them for their use. Every grinding-machine builder has done his best to make machines that would produce crankshafts satisfactory to the trade, but more or less trouble in obtaining a satisfactory product has always been experienced. In the last 2 years still newer types of machine for grinding crankpins have been developed and installed in a number of automobile factories. These employ a new method of driving the work-spindles and eliminate the use of gears.

The machine illustrated in Fig. 13 has met the demands of the automotive industry for a complete self-contained unit. The ground product has been greatly improved and the production considerably increased over that from older types of crankpin-grinding machines.

Automatic wheel in-feed mechanisms for semi-automatic crankpin grinding of the design shown in Fig. 14 have been introduced in this as well as in other new and heavier machines. As a result, in some places the operator merely clamps a crankshaft into the work-holders, pushes the lever shown at the right of the wheel-feed gear over to the right, and releases the automatic steady-rest-lever illustrated in Fig. 15. The pins are either rough-ground or finish-ground automatically with from a 15 to 25-per cent increase in production over previous methods, with less wheel-cost and a very satisfactory finished product.

The machine shown in Fig. 13 can be said to meet the demand for smoother running machines for this class of work and the traditional belief that gears produce chatter-marks has been considered. The gears have been replaced with a silent-chain running from the lower drive-shaft to the table drive-shaft and other chains from both ends of the table drive-shaft to each revolving spindle. Where these machines have been adopted there have been *no* complaints of chatter-marks in the crankshaft.

The automotive industry has become so huge that it must be regarded as the chief element of machine-tool business and the principal factor in forcing new developments in machine-tool design and construction. Competition among builders of internal-combustion engines constantly calls for greater production and machines of greater precision. The desire of those most interested in furthering developments along the grinding line is to originate, instead of to copy some of the present achievements. To copy is not progressive; to originate is to progress.

OUR "INVISIBLE" EXPORTS AND IMPORTS

For 1922 there was due us from foreign countries, from the excess of our exports over our imports of merchandise, an amount of $754,000,000. However, when we take into account such "current invisible" items as the movement of interest, remittances of emigrants, tourist expenditure, ocean freights, etc., we find that our citizens have sent to or spent in foreign countries a net balance of about $425,000,000 more than we received on such accounts, and thus the balance due us arising from merchandise is reduced to about $329,000,000. As offsetting this sum we have received about $246,000,000 net gold and silver imports and in addition there has been the invisible movement of loans and credits. We have exported capital in the shape of purchases of foreign securities, etc., and have received imports of capital of the same character to the net amount of about $660,000,000 in the year 1922, and were there no previous obligations to be accounted for this would amount to an investment abroad of more than the amounts due to us.

To visualize the full balance-sheet it might be stated that if we had entered the year with no obligations either way and if we had settled our balances in foreign trade and international finance every month in the year in gold, we should have exported gold to the amount of nearly $340,000,000 during the year, instead of having imported gold and silver to the amount of $246,000,000. As a matter of fact, the movement of our capital during the year was, as shown from the detailed study, partly a transformation of accounts due to our merchants and banks at the beginning of the year into bonds and funded debt during the year and partly a reinvestment abroad of amounts due us for merchandise sold during the year. No statement, however, as to the precise interaction of "invisible movements" can be considered in any other light than as illustrative of their relative importance, as from the very nature of things no set-offs can be stated in precise terms.—Herbert Hoover, Secretary of Commerce.

Motor-Truck Radiator-Design

By R. S. Wentworth[1]

SEVEN requirements appear to be the minimum number dictated by the necessity for greater reliability of truck radiators. They are offered as a means of analyzing past performances and indicating future changes in design. The value of the requirements lies not so much in the recognition of any single one as in compliance with the entire number. Since each requirement is essential in meeting certain definite conditions and since any one or more of these conditions might occur in the reasonable operation of any truck, no requirement may be neglected.

A radiator is strong and satisfactory only to the degree that it has no weaknesses, because it is these weaknesses that prevent the average radiator from being well balanced and strong. If the application of these requirements is made correctly, I feel very confident that radiator repairs can be reduced to an almost negligible quantity in any service for which the truck is intended. Thus, in discussing the general requirements for radiator reliability, I mention a minimum number that I believe must be observed, and I think it is essential that the designer recognize all possible stresses and their effects, even though he considers them of minor importance. Frequently, the sum of two small stresses exceeds the magnitude of a more obvious stress for which provision has been made, and I believe that this, rather than inherent frailty, has been the cause of most of the trouble experienced with radiators.

The Seven Requirements

(1) The radiator shall be designed and supported so that distortions of the frame shall not cause stresses within the radiator

(2) The raditor frame, shell or casing shall be structurally strong to withstand both internal and external stresses. The top, the sides and the bottom should form a unit of rigid construction holding the more delicate parts without transmitting twists or other strains

(3) Vibration of the tubes or any other part of the radiator shall be controlled and reduced to a minimum

(4) The radiator must withstand the effect of all possible temperature conditions without being subjected to undue stresses in any part

(5) The maximum possible stress on any tube joint shall be low

(6) Complex or indeterminate stresses in the tube joints shall be avoided

(7) Soldered joints shall be designed correctly and have ample bearing surfaces

Regarding (1), no truck frame is immune from twisting and no radiator has the characteristics of a cross-member. The designer should recognize these conditions by his choice of position and means of mounting. Many examples will be found in old trucks where frame stresses are transmitted to the radiator to such a degree that it is impossible to keep it from leaking without changing the method of mounting.

In reference to requirement (2), many instances occur where insufficient rigidity of the frame is caused by improperly designed side-pieces, poor choice of material or too light construction generally. When such radiators are subjected to rough usage, the strength of the core is called upon to do work for which it was not intended and failure is a certainty at the tube joints and elsewhere.

Vibration, (3), is a sure sign of uncontrolled stresses, a cause of trouble and a source of fatigue in any metal. While the amplitude of the vibration of the tubes may not be great, the force often is very large and the joints soon fail through repeated stresses of tension and compression that reach a maximum when the tube joint is bent. Therefore, it is imperative that the designer control vibration well within the limits of the strength of the solder joints. Tube vibration is affected by the choice of material, bracing, section, diameter and header-plate characteristics.

Concerning (4), in radiators of the heavy-duty type comprising cast top and bottom tanks spaced by rigid side-pieces, a great opportunity exists for temperature changes to alter the relative lengths of the core, the tubes and the side-pieces and thus impose high tube stresses on the header-plates. In such designs, the height of the core equals that of the side-pieces when bolted together at room temperature. Failure occurs most often in very cold-weather operating with such heavy loadings as to necessitate low-gear work and a high water-temperature. The result of these conditions is that the brass tubes of the core increase in length with a rise in the temperature from approximately 70 to possibly 200 deg. fahr., a change of 130 deg. fahr., while the side-pieces are shortened by a drop to the air temperature, a possible change in the temperature being 50 deg. fahr. or more.

These changes in the length must either cause the headers to bend or crack, the core to be compressed or the tube joints to fail; but, in any case, the stress is imposed on the soldered tube-joints in the headers. The designer of this type of radiator is cautioned against disregarding the effects of the temperature on the score of unimportance, for, though the actual distance through which the headers move may be very slight, the stress per tube runs very high and this is the dangerous condition to be avoided.

In regard to requirement (5), solder has not the qualities necessary for withstanding great stresses or repeated small ones. Good practice is to divide the total load equally among all the tubes; when this is done, the strain per tube can be handled easily and the factor of safety will be large.

To comply with requirement (6), the design should confine the stresses to tension or compression. Where complex stresses are permitted, it is most difficult to estimate their magnitude. Complex stresses occur if the headers are allowed to bend, the tubes to vibrate or the whole radiator to weave. Many incorrect designs are in use which use light headers that fail because of the joint angularity caused by the weight of the core, the temperature conditions and the proximity of the tubes to the rigid tank, together with the stiffening effects of the solder on the headers and the loss of flexibility of light headers when bolted firmly to the tanks. It is interesting to note the preponderance of leaks on the outside rows of radiator tubes, caused by these tubes being subjected to more conditions than the inside tubes, and justifying, to my mind, the necessity for recognizing *all* controlling causes.

The design of the soldered joints, (7), the properties of the solder and correct manufacturing methods are understood by the better class of radiator manufacturers. The joints should be amply strong to avoid failure caused by production methods and hard usage.

Summary

As long as designers fail to provide for the effects of all possible conditions, the radiators they design must fail in service eventually. The more logical procedure is to provide individually for each possible stress, so that it cannot cause trouble alone or in combination with the other stresses. For example, since the bad effects of frame weaving, tube

[1] President, Wentworth Engineering Co., Bryn Mawr, Pa.

possessing great strength. To expect a commercial product of engineering so free from inherent weakness that the life of each component will be the same, and the final failure from old age will occur anywhere and everywhere in a general collapse, is not asking too much.

THE PETROLEUM INDUSTRY

holdings, which are not infrequently as small as 10 acres each, overlie a common pool, or reservoir, of oil. As every gallon extracted by one well reduces the potential production of those surrounding it, the drilling develops into a race in which each producer tries to get the oil before someone else gets it. This situation has two important effects. The first is a strong inducement to the competing producers to extract the oil with the greatest possible speed, an inducement that only a ruinously low price of crude petroleum could remove. The delicate adjustment of supply to demand that is a feature of most competitive industries is destroyed, and the production of crude petroleum continues unchecked in spite of the immense stocks accumulating in the tanks of pipe-line and refining companies and the heavy reductions in the prices of crude and of refined products. The second effect of this competition in oil production is the waste occasioned by the loss of pressure. Oil generally occurs in close association with gas under high pressure, which materially lessens the difficulties and expense of extracting it. This pressure, of course, is never of sufficient duration to force all the oil to the surface; but, under the most favorable conditions, it frequently continues for long periods. Obviously, the "punching" of the pool at thousands of points results in a very great waste of pressure and not only advances the stage in which the product must be pumped to the surface at a considerably increased cost but makes impossible the recovery of some of the oil that might otherwise be available.

Although pipe-lines have been held to be common carriers under the jurisdiction of the Interstate Commerce Commission and as such are under obligation to accept and transport oil belonging to others, as a matter of fact the pipe-line companies buy most of the oil outright at the fields. Pipe-line carrying rates and the prices paid for petroleum at the wells have usually been such as to make it more profitable for producers to sell their oil at the wells than to transport it any considerable distance.

Early in 1922 David White estimated the reserve supply of the world at 70,000,000,000 bbl. and that of the United States at slightly more than 9,000,000,000 bbl. This means that in 1921 this Country's supply was being depleted at an annual rate of more than 5 per cent, and that the rest of the world at less than 0.5 per cent. The increased production and the shrinkage of the reserves in the United States since 1921 would, of course, make the present rate of depletion even more striking.

Nothing in this condition should occasion immediate alarm. The worst that may be expected in the measurable future is an increasing reliance by this Country upon foreign oil reserves and ultimately higher prices. Fortunately, the known world deposits are ample for prospective needs for many years to come, and future discoveries may add greatly to the available resources. Meanwhile, against the rapidly expanding requirements may be placed possible new processes and inventions that would introduce hitherto unknown economies in the preparation of petroleum products and in their utilization. These considerations do not, however, justify a heedless and premature exhaustion of a leading natural resource, but indicate the necessity of a progressive adaptation of the industry to the Nation's current economic requirements with a reasonable regard for the welfare of future generations.—*Guaranty Survey.*

Some Notes on Brake Design and Construction

By H. M. Crane[1]

Metropolitan Section Paper *Illustrated with* Chart

BRAKES have three functions: (*a*) maintaining a car at rest, (*b*) reducing the speed of a vehicle or bringing it to a stop, and (*c*) holding a vehicle to a constant speed on a descending grade. The kinetic energy of a moving vehicle is directly proportional to the weight of the vehicle and to the square of its speed. The amount of heat produced in the braking surfaces of a vehicle descending a given grade for a given distance will be the same whether the speed be high or low, but the rate of heat production will vary inversely as the speed. In addition to the retarding effect of the braking system a braking effect is constantly present that depends on the tractive resistance of the vehicle at various speeds and on the engine itself. Wind resistance and the resistance of the engine when the throttle is closed also produce retarding effects that assist in the work of braking.

Among the desirable features that should be kept in mind in designing brakes are (*a*) the maximum retarding effect with reasonable physical effort on the part of the driver, (*b*) smoothness of retardation, (*c*) a retarding effect proportional to the pedal pressure, (*d*) no tendency to be self-locking, (*e*) durability or long life, (*f*) ease and simplicity of adjustment, (*g*) strength, easy operation and thorough dependability and (*h*) brake-operating levers that may be easily and quickly reached in emergency.

The power available for operating brakes is a pedal movement of 4 to 5 in. coupled with a foot pressure that varies with the person operating the brake; consequently, brakes should be designed for the weakest driver. A properly designed mechanism will sometimes accomplish the same result with one-half the pedal movement that is required by another linkage of the same type but of inferior design. The linkage should be simple and direct, and the relation of the centers of the connections that operate the brakes on the axles and the wheels should be carefully studied so that the relative motions of the axle and the frame will not affect the linkage. If the major part of the multiplication of leverage takes place at the brake-drum the strains in the operating mechanism will be reduced to a minimum and the longitudinal motion will be increased to a maximum. In any design the two points to be kept in mind are a low rate of wear and a high rate of heat dissipation. In general, large linear dimensions are desirable but better air-circulation sometimes makes smaller sizes preferable. In light cars weight is of importance, while in heavy cars size is the controlling consideration. Unit pressures depend largely on the materials used; a brake-drum with hard surface with a lining of suitable material may enable higher unit pressures to be used than a soft surface with a lining inherently weak. Most brakes depend on either the external or internal application of shoes or bands. The features of the band type are light weight and a large friction-area. The external band is easier to design as the anchor point can be placed in any position desired. To obtain smooth action and long wear from a shoe-type brake, rigidity of both the drum and the shoes is essential. The balance of advantage appears to be in favor of the contracting-band brake, especially when the travel is over hard-surface roads. The requirements of braking materials are that the drum be as hard as is commercially possible and retain its hardness when heated, while the brake-lining should be close-grained and hard with a uniform coefficient of friction throughout its life.

MUCH of the difference of opinion that invariably appears when automobile brakes, or braking systems, are discussed undoubtedly arises from the widely different services required of such brakes, or braking systems, under varied conditions of use. For this reason, it appears to be worthwhile in starting a further discussion of this important subject to summarize briefly the more important functions of brakes.

Braking Functions

Probably the simplest of these functions is to maintain the vehicle at rest on a level surface or on a grade; another function is to reduce the speed of a moving vehicle or to bring it to an absolute stop, either on a level surface or on an ascending or a descending grade; still another function is to cause the vehicle to maintain a constant speed on a descending grade. The first function mentioned, that of maintaining the vehicle at rest, obviously is the simplest one. The main requirement is that of multiplying the leverage from the operating lever to the braking surface, and of combining it with the leverage relation of this surface and that of the road wheels and with the two coefficients of friction, so that it shall be sufficient to lock the wheels under all conditions. As there is no motion involved in this case, no heating conditions need be considered and no particular smoothess of operation or resistance to wear is required; and even inaccurate connections between the frame and the axle may not cause trouble. As soon, however, as the vehicle is in motion and the braking system is in use, a very different set of conditions exist that requires the highest skill of the engineer in order that a satisfactory arrangement may be produced.

In this discussion, I shall consider only the ordinary type of brake in which a stationary surface is pressed upon a moving surface driven by the vehicle wheels, with the result that the energy present in the moving vehicle or produced by the descent of the vehicle from a higher to a lower level is translated into heat by the friction between the relatively moving surfaces. The energy present in any moving vehicle, of course, is directly proportional to the weight of the vehicle, as is also the energy given up during the descent of the vehicle from a higher to a lower level. The energy present in a moving vehicle due to its speed is proportional to the square of the speed.

The maximum force of retardation possible is pro-

[1] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

(3) *Retarding Effect Directly Proportional to the Pedal Pressure.*—This is necessary to allow accurate control of the braking effect under different conditions of road surface. It can be obtained only where there is a minimum of friction, uniform friction and uniform spring throughout the brake-operating mechanism

(4) *No Tendency to Be Self-Locking.*—This is, to some extent, another way of stating the previous requirement. It is not exactly opposed to brakes of the wrapping type, although it is very difficult to design such brakes without some of this undesirable feature. It is intended to apply more directly to mechanisms that have a tendency to jam under certain conditions, which makes it difficult to reduce the braking effect without almost completely releasing the brake and reapplying it

(5) *Durability or Long Life.*—The result of this is shown in the infrequent necessity for replacement of friction surfaces and the correspondingly infrequent adjustment

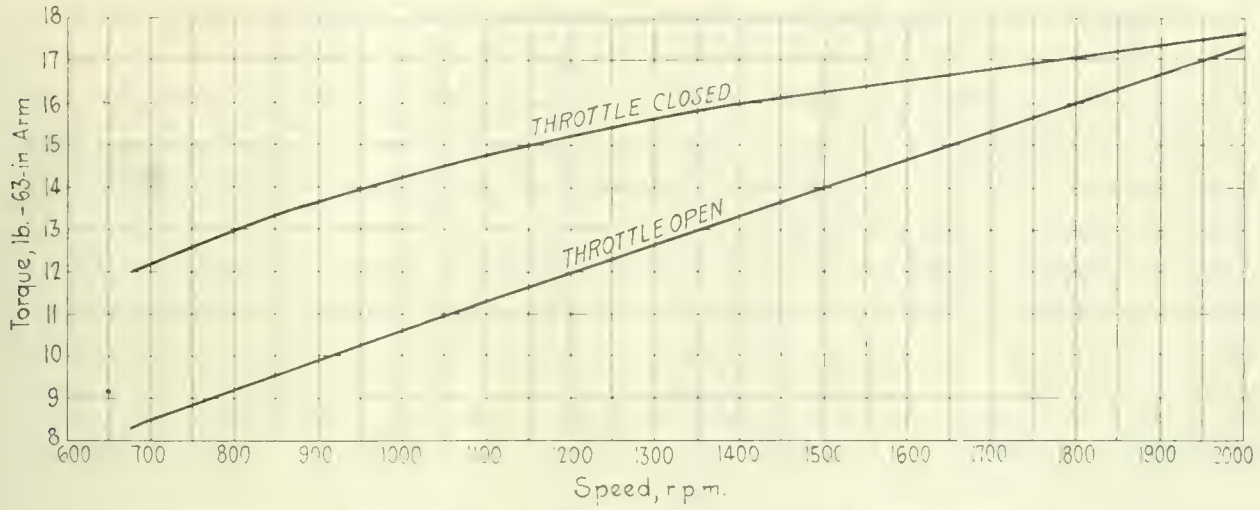
(6) *Ease and Simplicity of Adjustment When Adjustment Is Required.*—Uniform action under all conditions, that is, the retarding effect, must be maintained throughout long and severe brake applications and must not be altered materially by weather conditions or outside causes. Of course, the latter point refers only to the brake mechanism and cannot be controlled as regards the road surface

(7) *Need for Strong Locking Devices for Brakes.*—The locking device for the hand brake, or other car-locking brake, must be strong, easily operated and thoroughly dependable. This locking equipment is really a safety device of great importance and when inefficient has been the cause of serious accidents

(8) *The Brake-Operating Levers Must Be Easily and Quickly Reached in an Emergency.*—This applies equally to the foot-pedal, which ordinarily operates the service brake, and to the hand-lever, which operates the so-called emergency brake. As a matter of fact, in current practice, the foot-pedal is the real emergency brake, the hand brake being used only when the foot-operated brake fails to produce the desired result. This being the case, it is obvious that the greatest care should be taken to place the foot-pedal in a position that can be reached with a minimum of motion and a maximum of certainty. This requires careful consideration of its relation to the accelerator pedal, with a view to making the transition of the foot from the accelerator pedal to the brake pedal as smooth as possible, and to insuring that the operation of the brake-pedal cannot result in the depression of the accelerator pedal at the same time.

Power Available for Operating Brake

Disregarding for the moment various forms of servo mechanism, the power available for operating brakes may be stated approximately as follows: For the foot-operated brake, a pedal movement of from 4 to 5 in., coupled with the maximum convenient foot-pressure. This latter, of course, will vary with different persons, and it is desirable that the mechanism be designed for the weakest driver that may have to operate the vehicle. It should be borne in mind that the clutch is frequently thrown out at the same time that the foot-brake is operated, an act that will absorb from 30 to 50 lb. of the available force. For the hand-brake, a total motion of from 12 to 15 in. may be used, coupled with the driver's available pulling power. It is recognized that



Results of a Test of a Six-Cylinder Passenger-Car Engine Showing Its Effectiveness as a Brake

greater pedal and hand-lever motions are frequently provided than those stated above, but they cannot be provided without making the brake operation much less convenient and more uncertain in cases of emergency. Of course, by the use of some form of servo mechanism, varying from the wrapping type of brake to the entirely separate mechanism in which the driver supposedly furnishes the control and the mechanism furnishes the power, almost any results are possible. There is nothing new about servo mechanism for this work. The horse-drawn Paris omnibuses of 1888 were equipped with shoe brakes pressing against the rear tires, the greater part of the power for application being provided by several turns of rope wound around bronze capstans on the hubs.

Brake-Operating Mechanisms

This paragraph is placed directly below the preceding one to emphasize the close relation between the two. In the simplest terms, the possible pressure of a brakeshoe or band on a drum is the push of the driver's foot or the pull of the driver's hand multiplied by the total distance traveled by the driver's foot or hand and divided by the total distance traveled by the brakeshoe or band. From this must be subtracted the losses due to friction in the operating mechanism and to the lost motion and the spring in the parts. It is entirely possible for a well-designed set of brake connections to accomplish the same results with one-half the pedal movement that may be necessary in using another linkage of the same type but of inferior design. There have been too many cases in the past in which either excessive pressure has been required for a given braking effect or the actual motion of the bands or shoes has been reduced to such a point as to make correct adjustment difficult and frequently necessary. In some cases, either the brakes will not hold properly when applied or, if adjusted to do so, will drag when released as fully as possible. Some principles that have been found to be of great help in producing the best results are as follows: Have the linkage simple and direct; use the greatest care in studying the relation of the centers of the connections that operate the brakes on the axles and the wheels so that the relative motions of the axle and the frame will not affect the operation of the linkage. It is entirely possible, even with cars using the Hotchkiss drive, to accomplish this desirable result in an almost perfect manner; to do so, it is necessary to bear in mind that the axle rotates more or less because of the torque-reactions produced in braking. It has been found to be of great assistance in handling this difficult portion of design to have the major part of the multiplication of leverage take place at the brake-drum. If this is done, the strains in the operating mechanism will be reduced to a minimum, while the longitudinal motion will be increased to a maximum. Obviously, if the brake rods leading from the frame to the axle move 6 in. during the application of the brakes, the effect on braking of the variations in centers will be far less than if the motion is 2 or 3 in.

Design and Construction of the Brake Mechanism

It is practically universal practice with brakes to provide a rotating cylinder that is retarded by the pressure of a shoe or band, either external or internal. Occasionally disc-type brakes have been suggested, but they do not seem to offer any particular advantage. Keeping in mind the work to be done by a brake, there appear to be two points of importance that must be worked out in the design, one being the low rate of wear, the other, a high rate of heat dissipation. Low rate of wear, other things being equal, will, of course, be obtained best by low unit-pressure between the rotating cylinder and the friction band or shoes. This requirement indicates the desirability of brakes of large linear dimensions. Large linear dimensions are also of considerable value in obtaining a high rate of heat dissipation; but it must be borne in mind that in long continued brake applications the heat dissipation will be governed largely by the ability of the brake mechanism to transfer heat to the surrounding air. For this reason brakes of small size that provide rapid air-circulation may easily be more effective than much larger brakes that are more or less shielded from the air by parts either of the brake mechanism or of the car. Large and heavy brake parts have an advantage in that they can absorb a great quantity of heat during a short brake application, the heat being gradually dissipated to the air during the intervals between the applications. As a matter of fact, the ability to dissipate heat is closely connected with the ability to resist wear, for the reason that in almost all combinations of braking surfaces the wear becomes much more rapid as the temperatures become higher. This is probably due, fundamentally, to the softening of the metal or metals used as the temperatures become higher. About the hardest problem the car designer has to face in laying out brake equipment is to decide as to the sizes and weights that can be allowed. In the lighter

cars the weight question is of great importance, as there is usually room for brakes much larger than those commonly used. On heavy cars the limitation as to size appears to be more important and affects both the diameter and the width that are possible without seriously compromising other features of the car design. The use of smaller wheel centers has resulted in a very serious limitation of the diameter of wheel brakes, while the diameter of the propeller-shaft brake is closely limited by the road clearance and the space available under the floor of the car. There is one very unfortunate complication in brake design, due to the necessity for protecting the brakes from mud and dust to obviate wear. It is almost impossible to accomplish protection of this sort without interfering considerably with the proper dissipation of heat. In emphasizing the desirability of low unit pressures, it should be remembered that no absolute figure can be given, as the maximum safe unit-pressure depends on the materials used in the brake-drum and the friction surfaces. If the brake-drum has a very hard surface and a suitable friction lining is used, it is possible to use unit pressures much higher than if the drum surface is soft and the friction lining inherently weak. In any case, it is highly desirable to keep the unit pressures as low as possible, both by using as large brake dimensions as the design will permit and, especially, by seeing that the pressure shall be uniformly distributed over the whole braking surface. So far as I can see at the present time, it is hardly necessary or desirable to provide 100 per cent braking for all possible conditions of service without the use of the engine. The tax would be too great on the average car user and would be merely for the benefit of the user traveling in mountainous country at fairly high speed. The engine is so excellent a brake that, under suitable conditions, it seems only reasonable to expect that it will do its share of the work.

Types of Brake-Drum and Band or Shoe Design

Design has crystallized into relatively few major variations of members; thus we find either internal or external application of either shoes or band. The general features of the band type are light weight and a large friction-area for a given size of drum. The light weight is due to the fact that with a properly designed band-brake there is very little tendency to distort the drum, and that minor distortions of the drum will not interfere with smooth brake operation. The large area of contact is due to the ability of the band type to utilize the entire circumference of the brake-drum while still providing the proper clearance when released. The external band is considerably easier to design, as the anchor point can be placed in almost any desirable position, depending upon the wrapping effect required. This is not true of the internal band, which requires that it be of the wrapping type to spread the pressure over the whole available surface. It is only the compression side of an internal band that is used to advantage, the tension side tending to pull away from the brake-drum and to concentrate the pressure at the ends. An advantage of the band type is its ability to provide almost the entire multiplication of leverage directly at the band, and the least adjustment as well. The band brake, unless it is of fairly expensive construction, is more likely to rattle and is harder to keep from dragging than is a properly designed shoe brake. On wheel brakes this undoubtedly interferes to some extent with the proper dissipation of heat. On a propeller-shaft brake this is not the case, as in this type it is very easy to provide internal air-circulation. The shoe-brake usually consists of fewer parts of larger size and accordingly has a decided advantage. On the other hand, it is almost impossible to provide a means of ready adjustment for a shoe-type brake without placing a large part of the multiplying leverage somewhere in the brake linkage, instead of at the shoes. This greatly increases the friction in the applying mechanism, the friction being still further augmented by that of the cams used in expanding the shoes, if an internal type is used. External contracting shoe-brakes are hardly ever used, except on the propeller-shaft. With the contracting type the operating mechanism can be made very similar to the operating mechanism of the band brake. The heavy weight of a properly designed shoe-brake is due entirely to the need of rigidity and to the fact that when only two shoes are used it is hardly possible to use more than one-half the available drum surface for friction, about 90 deg. being taken by each shoe. Though more of the circumference can be used, any attempt to do so will make it difficult to obtain the proper clearance between the drum and the shoes when the brake is released. To obtain smooth action and long wear from a shoe-type brake, the drum must be rigid enough to stay truly round, and the shoes must be rigid enough to retain their shape under the maximum pressure used. This can only be accomplished by heavily ribbing both the drum and the shoes. Another reason for the desirability of a rigid drum and shoes is the limited motion and power available for comfortable brake operation. Any spring in these parts must be absorbed before the maximum pressure is reached and is far more serious than a spring in other parts of the brake mechanism, because the maximum leverage has been provided at this point. I have suspected that a great part of the advantage of a heavily ribbed brake-drum is due to its weight and rigidity rather than to any greatly increased area for dissipating heat. The external-contracting brake, whether of the band or shoe type, has a distinct advantage over the internal-expanding brake in that the braking ability tends to improve over long continued application rather than to decrease. This is on account of the expansion of the drum and other brake parts that is caused by the heat absorbed. Of course, this applies more strongly to the present conventional brake design in which the drum is of metal, and the friction surface is asbestos fabric or some other relatively poor conductor of heat. My own feeling is that the balance of advantage is in favor of the contracting-band brake, especially in districts where the great bulk of travel is on hard surface roads.

Brake Materials

There is not a great deal to be said on this subject without going into a long investigation of brake-lining materials. There are, however, one or two important points. The brake-drum, which is ordinarily of steel, should be as hard as is commercially possible and should retain its hardness when heated. The brake-lining material should also be close grained and hard, and should have a uniform coefficient of friction throughout its life. This is highly important on all types of wheel brake, because of the fact that equalization, even when it is provided, only attempts to equalize the brake-shoe or band pressure. I have found it to be of considerable advantage to treat brake-linings occasionally with oil, in order that the binder shall be maintained in efficient shape. I have never seen any asbestos fabric that showed much cohesive quality after being completely dried out by high heat.

ST. LOUIS AIR MEETING

IT has been said truly that correct forecast of the future is rare because it must be founded upon a disbelief in the stability of things as they are. Life overleaps every bound that is set. The prime elements requisite in progress have to be sensed and developed by groups of relatively few men. The public in general is always slow to appreciate the coming of changes that affect life fundamentally.

The airplane races held at St. Louis last month formed a fitting climax to such recent events as the successful trials of the Barling Bomber; the Air Service mobilization test along the eastern seaboard; the successful trials of the ZR-1, recently rechristened the Shenandoah; the bombing tests off Cape Hatteras; the opening of the Boston airport and of the Louisville airport; the Transcontinental airplane flights; the winning of the Schneider Cup in the seaplane race at Cowes, England, by the United States Navy Team; and the night flying of the Air Mail Service from Chicago to Cheyenne. The work of engineers engaged in and in connection with aeronautics, following in the footsteps of masters in pioneer aviation, has involved almost unparalleled research connected with raw and finished material. To this is attributable the remarkable achievements of today, including speed, altitude and duration performance. Each and every part has been subjected to long and accurate tests to bring about simplicity, strength and lightness through proper distribution of material according to mechanical laws. The importance and the value of passenger and freight carriage by aircraft are self-evident. Taking into account the fact that air transportation is inherently different in basic characteristics from practically all other forms of transportation, it is probably fair to say that it is not less developed or to be debited with a greater percentage of casualties than the other mediums of transportation were after the expiration of the same number of years during which serious concerted attention has been given to commercial aircraft development. The Society of Automotive Engineers took concrete steps several years ago to establish in conjunction with the Bureau of Standards a safety code for aeronautics. Good headway has been made in the tentative formulation of this code. Various parts of the code, which deal with airdromes and airways, balloons, airships, and airplane structure, have been drafted. All of the governmental and industrial bodies interested in aviation are participating in this work, which is being conducted through a sectional committee of the American Engineering Standards Committee. The purpose is to have ready a well considered document setting forth regulatory needs and provisions when some department of the United States Government is authorized and directed to put such regulations into effect.

Responsibilities of Development and Defense

As was pointed out at the sessions of the National Aeronautic Association in St. Louis, a great responsibility rests upon those who understand what aircraft development means. In the last analysis the maintenance of adequate aeronautic activities depends, and will depend, upon the degree of aggressive spirit fostered by the public. The National Aeronautic Association can, and should, be most helpful in this connection. The Congress must have brought to its attention clearly the necessities of the Air Service. The greatest need is the enactment of legislation that will result in the enforcement of governmental regulations such as those referred to above. Of course, there should be adequate preparedness with regard to aircraft in the event of war. The development of civil air transport is absolutely essential to this.

At the National Aeronautic Association Dinner in St. Louis, Dwight Davis, assistant secretary of war, expressed cordial sympathy with the industrial work in the aeronautic field. He said that the men in the War Department realize the importance of this more than anyone else and will always cooperate fully. He predicted that complete flights across the United States from the Atlantic to the Pacific will be made between dawn to dusk and to China in 100 hr. He said that we are doing pitifully little in the way of preparing to meet successfully invasion by enemy aircraft. Congress has reduced our Air Force unduly, which has not proper equipment and less than 1000 officers. There is now an actual shortage of planes for some purposes; our most important arm of defense is being starved to death. An aeronautic industry cannot be built up overnight during wartime. Aircraft are indispensable during war.

Mr. Davis said that he did not believe in building up a large air fleet but that we should have a 10 years' program to provide a basis of procedure and give the airplane builders sufficient orders to remain in business. He stated that all of the leading nations except this Country are giving these matters close and constructive attention.

Major-General Patrick, chief of the Air Service of the Army, pointed out that we can produce airplanes that are unexcelled, and that we have the best of pilots, but that we do not really put aircraft to work. He said that the continuance of this policy would result in this Country losing much in the commercial markets of the world.

Rear-Admiral Moffett, chief of the Bureau of Aeronautics of the Navy, stated that the Navy is twice as badly off as the Army is. Referring to airship development, he said that the Shenandoah is not a copy of foreign products but was designed by Americans and made of American material. He expressed strong belief in the future of airships, stating that they can navigate with the aid of the barometer and knowledge of the weather conditions. Cruising at 60 knots, they can avoid storms. It is the intention of the Navy Department to send airships across the Atlantic, to the North Pole and around the world. The Admiral said that the Shenandoah should be able to cross the Atlantic in 2 days, and the Pacific in from 3 to 4 days. He declared that this Country has the greatest of opportunities before it in aircraft development and should proceed carefully and thoroughly in demonstrating the new means of passenger and merchandise transportation.

Commander Billard, of the United States Coast Guard, said that this Country should be second to none in National defense. The Coast Guard, which was organized in 1790, has participated in all of the wars in which this Country has been engaged, its percentage of battle losses being greater than that of any other arm of the services except the Marines. Coast Guard aviation is of direct assistance in National defense. Aircraft are the greatest agency in searching territory, which is involved in all Coast Guard work.

Brigadier General Felend, of the United States Marine Corps, said that, whereas only a few years ago the older officers merely tolerated aviators, they now consider them serious, hard-working men. This new conception puts the Army as well as the Navy solidly behind aviation. The result should be the mightiest development in any one line of human endeavor.

Second Assistant Postmaster-General Henderson, in charge of the United States Air Mail Service, said that that Service, beginning in 1918, has an efficiency record of 96 per cent. During 4 days of August continuous day-and-night Transcontinental service was maintained, the westbound trips being made in 29 hr. and the eastbound trips in less time. Mr. Henderson said that it is entirely practicable to operate aircraft at night and that within a decade cities more than 500 miles apart may have day-and-night transportation. This will depend largely upon the cost of such service and the income derived therefrom, it not being known what the public would be willing to pay in postage charges for a service of this nature.

Howard E. Coffin was reelected president of the National Aeronautic Association, but resigned the office, which the

The Races

The Pulitzer Trophy race, which was won by Lieut. A. J. Williams of the Navy, at an average speed of 243.67 m.p.h. over a distance of 124.27 miles. The machine was a Curtiss R2C-1 with Curtiss D12 special engine rated at 507 hp.

The Flying Club of St. Louis Trophy race, for two-seaters of 90 hp. or less, military only, was won by Walter E. Lees with a Curtiss JN4 airplane at an average speed of 89.31 m.p.h. The distance was 79.21 miles. The machine was equipped with a Curtiss OX5 engine.

The Liberty Engine Builders' Trophy, for observation type aeroplanes, military only, was won by Lieut. C. McMullen, in a Packard 0-1 with a 400 hp. Liberty engine, at an average speed of 139.03 m.p.h. over a distance of 186.42 miles.

A Nieuport won the Aviation Country Club of Detroit Trophy in a Bellanca CF with an Anzani 95-hp. engine, over a course of 155.34 miles at a speed of 94.80 m.p.h.

The Manufacturers Exchange of St. Louis Trophy race was won by Lieut. H. L. Clinger in a Martin Bomber with two Liberty 400-hp. engines, over a course of 186.42 miles at a speed of 114.28 m.p.h.

The Detroit News Air Mail Trophy event for Air Mail planes, with Air Mail pilots, over a distance of 186.42 miles, was won by F. F. More with Air Mail Service airplane with a 440 hp. Liberty engine at 124.98 m.p.h.

The Mitchell Trophy race was won by Capt. B. E. Skeel in a Thomas Morse MB3 airplane, with a 300-hp. Wright H3 engine, at a speed of 146.45 m.p.h. The distance was 124.27 miles, the race being open to Army pursuit planes of military type.

The Mulvihill Model Trophy event, for model airplanes not exceeding 40 in. in span, driven by rubber-strand motors, for duration, was won by E. J. Lange of Chicago, with a model that maintained flight for 4 min. 22 3/5 sec.

C. S. Jones won the "On-to-St. Louis" race. He flew a Curtiss-Oriole biplane, carrying one passenger, from Garden City, N. Y. The St. Louis Chamber of Commerce presented the trophy for this event, which was for civilians only, the competitors to fly from any point over 200 miles distant, and the winner determined on the point basis, with credits for speed, distance, passengers carried and horsepower of engine used. Jones' flying time was 13 hr. 30 min.

HELIUM IN AIRSHIPS

THE estimated total output of helium from American sources is 30,000 cu. m. (1,059,433.67 cu. ft.) per day, of which approximately one-third could be collected readily at an initial outlay for the plant of about $70,000,000. Amortizing this capital outlay during the average life of the plant, which is estimated at 20 years, and adding the actual operating expenses, the minimum cost of compressed helium amounts to about $2 per cu. m. (7.1 cents per cu. ft.). This cost is based on a probable annual production of 3,000,000 cu. m. (105,944,136.8 cu. ft.) of helium.

The consumption of hydrogen gas in an airship is due (*a*) to osmotic diffusion, (*b*) to the necessary washings for maintaining a predetermined degree of purity and (*c*) to consumption during navigation. In the present state of technique and practical application, the most important of these three causes is the last, which in the case of the regular commercial traffic would assume very high values indeed. If the consumption is calculated for long distance flights and heavy yearly traffic, 4000 hr. of flying per year for example, and it is assumed that the quantity of hydrogen gas that must be lost to overcome the decrease in weight due to fuel consumption is 1 cu. m. per kg. (16.017 cu. ft. per lb.), the supply consumption of an airship having a volume of 100,000 cu. m. (3,531,445.56 cu. ft.) driven by engines developing approximately 3600 hp. and navigating at half power with an average hourly fuel-consumption of 500 kg. (1,102.31 lb.) is 2,000,000 cu. m. (70,628,911.20 cu. ft.) of hydrogen or 20 times its own value. Practically the entire American output of helium would be required for supplying a single airship on this basis and therefore the cost would be prohibitive. In practice occurring in actual practice it has been found possible to compensate for the fuel consumption during navigation. Consequently the most important of the three causes that make the supply of gas for an airship a serious question is capable of total elimination.

Although it has not been possible as yet to ascertain sufficiently exactly the coefficient of diffusion of helium through the different types of commercial fabrics, the experiments carried out at the Institute of Experimental Aeronautics at Rome and also in the United States show that it is not unreasonable to assume a loss of 2 liters per sq. m. (0.00978 cu. ft. per sq. ft.) in 24 hr. Basing our calculations on this figure the airship under consideration, which has a surface of diffusion of 18,000 sq. m. (115,251.1 sq. ft.), would lose through osmosis 19,440 cu. m. (686,513.07 cu. ft.) of gas per year, which is less than 20 per cent of its volume. The relative losses in the case of greater volumes would be even less due in part to the smaller surface-volume ratio.

At present the fresh supplies of hydrogen required on account of consumption during navigation are sufficient to maintain the necessary purity inside the envelope, but where fresh supplies are not available, the washing of the gas becomes a daily necessity, the importance of which is much greater than the actual losses through osmosis. If, for example, it is desired to maintain a purity of 96 per cent with an annual osmotic loss of 20 per cent as calculated above, an annual washing equal to double the volume of the airship is necessary. In the case of helium this cause of great consumption can be totally eliminated by regenerating or repurifying the helium, that is, extracting the air that vitiates it, and by cooling and liquefying the gas.

Of the three causes mentioned that render the replacement of helium necessary, consumption during navigation, washing and osmotic loss, which are in the proportion of 100 to 10 to 1, only the last, which amounts to an annual average of 20 per cent of the volume of supply, cannot be eliminated. This has two important results. First, the necessity of replacement being reduced to this single cause, the available quantity of American helium is sufficient for running not one, but 150 airships of the average volume mentioned above, which is sufficient for a world fleet of civil airships; and second, the cost of helium is within the reach of economical navigation, because apart from the volume of gas necessary for inflation only an annual replacement of 20 per cent of this volume is required. In other words, the initial gas volume necessary for inflating the dirigible is exhausted in a minimum period of 2 years. Considered in this light, helium is no longer a material of consumption but a material of construction of which the required initial outlay for the plant is amortizable in 5 years. Therefore, its substitution for hydrogen in civil enterprise is possible and economically profitable.—Col. A. Crocco in *Aviation*.

Spur-Gear Grinding and Testing

By A. J. Ott[1] *and* C. L. Ott[2]

Production Meeting Paper *Illustrated with* Photographs and Drawings

A GRINDING machine for finishing spur-gears is illustrated and described; claims are made that it will grind transmission gears on a production basis after they have been heat-treated, will produce correct tooth-contour, smooth finish and accurate tooth-spacing, these features being necessary in producing gears that are interchangeable and that run quietly.

This machine is of the generating type, its action being that of rolling a gear along an imaginary rack and using the grinding wheel as one tooth of the rack. The dished grinding-wheel is reversible, 30-in. in diameter, mounted below the gear, and can be swiveled to the right or left of the center position up to an angle of 25 deg. The work-spindle carries the indexing and the generating mechanisms at the rear, where they are accessible and yet are protected. Two or more machines can be operated simultaneously by one man, as a clocklike mechanism can be set to stop the work-carriage and the grinding wheel when the last tooth of a gear has been ground.

A drum-cam drives the work-carriage. Thin steel tapes are used to accomplish the generating principle; they wind and unwind on a pitch-diameter segment as the work-carriage is driven forward and backward, and produce uniform duplication of tooth-contour. Slight variations of tooth-contour can be made easily by giving a greater or a less angle to the wheel and also by varying the diameter of the pitch-circle or segment.

A machine for testing gears that have been ground is described also; it will develop the involute curve, indicate whether it is true or modified and test tooth-spacing. By means of adapters, engine-front spiral-gears, and bevel-gears, can be checked for accuracy of contour and for tooth-spacing.

LONG strides forward have been made in the grinding art in the past 20 years; I cite the plain cylindrical field as an instance. It is not so many years ago that the manufacturers of plain grinding-machines urged the economy of grinding; that is, the use of lathes for rough-turning shafts, spindles and the like, and then grinding to the limits desired, so as to insure interchangeability. Automotive engineers and manufacturers grasped and adopted the idea and its advantages quickly. No one would think now of finishing cylindrical parts on a lathe by the old methods; especially would they not think of hardening a part after finishing it to size. For example, in one of our machines, shown in Fig. 1, there is a spindle 3 in. in diameter and 34 in. long; it is of 3½-per cent nickel steel, pack-hardened and oil-quenched. We consider a 0.015-in. warp very little. Of course, the spindle is ground before it can be used.

Fig. 2 shows a transmission gear, approximately 6 in. in diameter, with a ¾-in. face, of 6 pitch and having a 5/16-in. web. This gear is ground on both sides before oil-hardening and, after it comes from having been heat-treated, its sides will show a warp from 0.005 to 0.015 in. The most careful chucking in grinding the hole from the pitch-line will not square-up the tooth bearing-surfaces, for they are no longer parallel. Furthermore, the tooth-spacing of the gear was very good in its green condition, and no interference could be noticed in testing this by hand-rolling; however, after heat-treatment, the

Fig. 1—A Gear-Grinding Machine Spindle That Is Ground Before Being Used

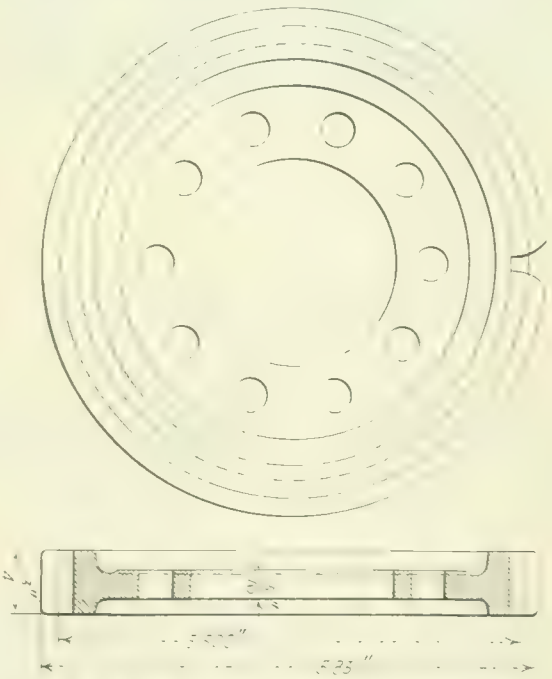


Fig. 2—A Transmission Gear Approximately 6 In. in Diameter That Is Ground on Both Sides Before Oil Hardening

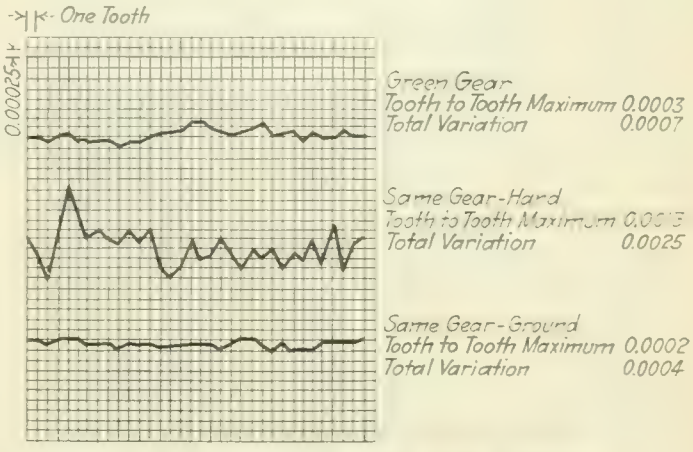


Fig. 3—Chart of a 33-Tooth Gear Showing Green, Hardened and Ground States

[1] President, American Grinder Co., Detroit.
[2] Secretary-Treasurer, American Grinder Co., Detroit.

FIG. 4—APPLICATION OF THE GENERATING PRINCIPLE TO GEAR GRINDING, THE GRINDING WHEEL BEING THE EQUIVALENT OF ONE SIDE OF A RACK TOOTH

tooth-spacing was bad, as shown in Fig. 3, and hand-rolling showed considerable interference. But the bearing surface of the teeth can be made parallel and concentric with the hole, the spacing made accurate and the tooth-contour restored with a grinding machine that we have developed.

DESCRIPTION OF GRINDING MACHINE

This machine is of the pure generating type, the action being that of rolling a gear along an imaginary rack with the grinding wheel used as one tooth of the rack, in the manner shown in Fig. 4. Fig. 5 shows a general out-

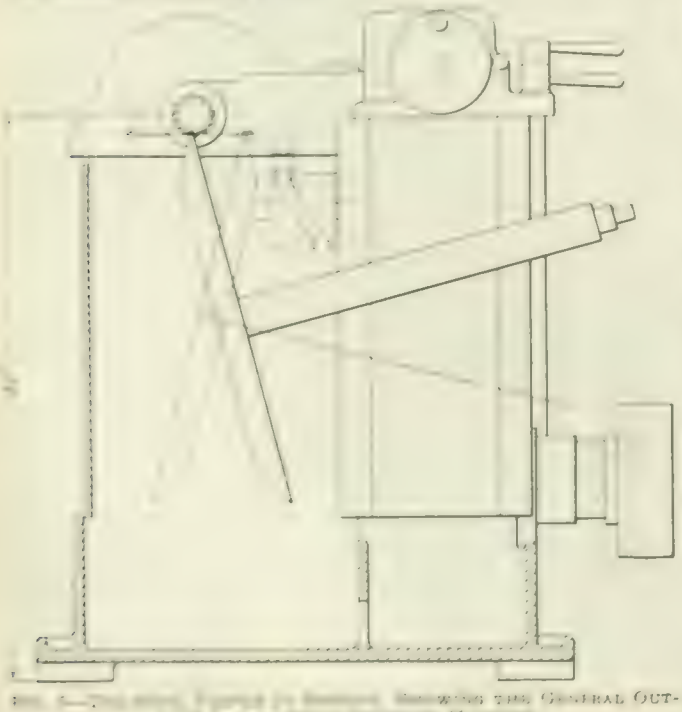


FIG. 5—THIS VIEW SHOWS THE GENERAL OUTLINE OF THE GRINDING MACHINE

line of the machine. The gear is mounted at a suitable loading height; the dished grinding-wheel, 30 in. in diameter, is below the gear and it can be reversed and swiveled either side of the center up to an angle of 25 deg. The work-spindle carries the index and generating mechanism at the rear, where it is protected thoroughly and is very accessible. The carriage is driven by a drum-cam, and a mechanism is provided that stops the carriage, and the wheel also, when desired. All control levers are immediately in front of the machine to the right of the wheel.

Fig. 6 is a front right-hand side-view of the machine, with the water-guard in place and covering the wheel and the work. The machine is self-contained, has a single-pulley drive, and its general compactness is noticeable. The wheel-spindle is journaled low on the wheel slide-column, and this brings the heavier and high-speed member down nearer the floor. It has a 1½-in. lateral-feed adjustment, and is provided with double end-thrust ball-bearings. The main bearings are made of the best

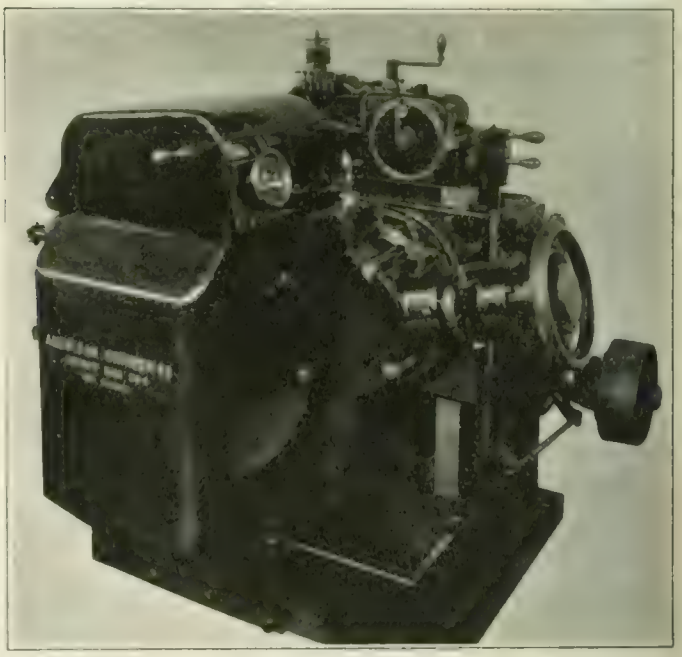


FIG. 6—THREE-QUARTER VIEW OF THE GRINDING MACHINE

bronze obtainable. The amount of feed is controlled by the 12-in. hand-wheel, which is provided with a micrometer adjustment and a positive stop. Fig. 7 shows a sectional sketch of the grinding-wheel and Fig. 8 shows its reversible feature.

The straight edge at right angles to the wheel-spindle does the grinding; it is kept true with a double worm-and-worm-wheel-driven truing-device. While rotating the hand-wheel moderately, the reduction is such that the movement of the diamond is slow, which is necessary to secure a smooth and true grinding surface. Our design of wheel allows a 1¼-in. deep surface-wear or truing. An average of one thousand 30-tooth gears of 6 to 8 pitch can be ground on both sides of the teeth with a No. 6636 Combination-J, vitrified wheel, which means two grinds or four passes; this equals grinding 60,000 teeth on one side, twice around, which is the usual grinding method.

The wheel-head is arranged to swivel to the right or to the left of the center, up to an angle of 25 deg. This is particularly advantageous when working on pinion gears, that is, gears with stems; the stem is located in

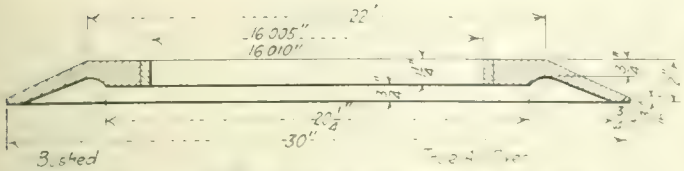


FIG. 7—CROSS-SECTION OF THE GRINDING WHEEL

the holding arbor while grinding either the drive or the coast side of the teeth and, without the swiveling feature, special outboard centers would need to be used, which would be rather inconvenient and not at all practicable in some cases. It is also a very desirable feature when working on some cluster gears; the wheel, of course, is reversed and so is the diamond-holding bracket.

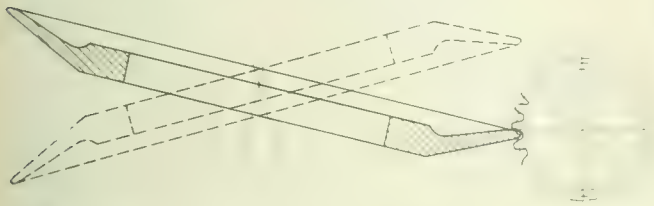


FIG. 8—SKETCH ILLUSTRATING THE REVERSIBLE AND SWIVELING FEATURES OF THE WHEEL

Fig. 9 shows the wheel-head swiveled to the right 20 deg. and grinding an 18-tooth 6-pitch stem-gear on the drive slide. Fig. 10 shows the wheel-head swiveled to the left 14½ deg. and grinding an 18-tooth 6-pitch stem-gear on the coast side.

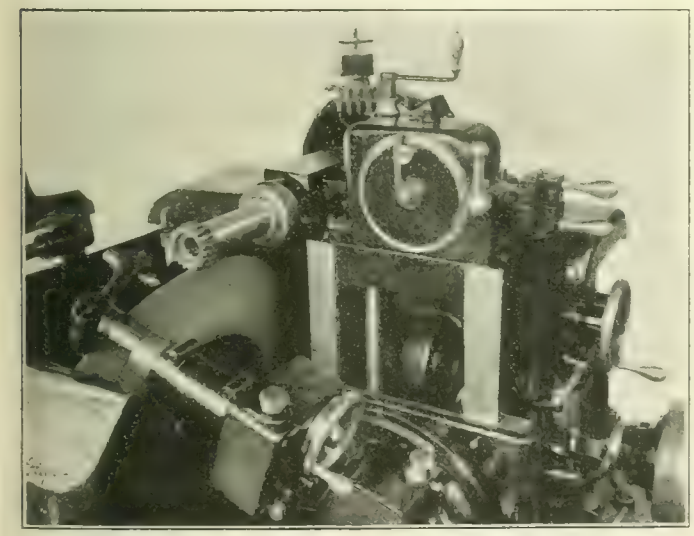


FIG. 9—GRINDING THE DRIVING SIDE OF AN 18-TOOTH STEM GEAR WITH THE WHEEL-HEAD SWIVELED 20 DEG. TO THE RIGHT

The position shown in Fig. 10 is that in which the wheel-head is used most, and on all gears that can be reversed readily. The gear above the wheel is at a suitable loading height and is very accessible. The water-guard is lifted and rocked-up out of the way. A clock-like mechanism automatically stops the work-carriage when the last tooth of a gear has been ground; it also stops the wheel if desired. It is customary to set the stop at twice the number of teeth of the gear that is being ground and to allow the gear to turn around twice; that is, to make what might be called a rough and a finish grind. During the second time around, there is no feed-up to the wheel; it is "sparking-out" as it were. Then, as the last tooth is finished, the carriage stops automatically and so does the wheel, if it is set to stop.

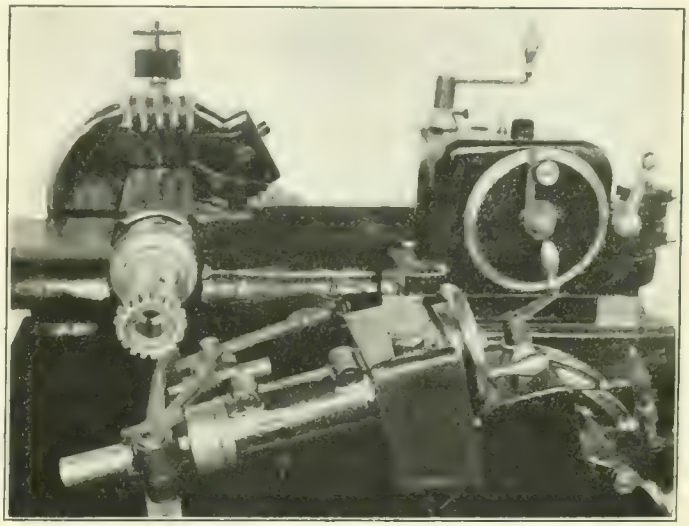


FIG. 10—THE WHEEL-HEAD SWIVELED TO THE LEFT 14½ DEG. FOR GRINDING AN 18-TOOTH STEM GEAR ON THE COAST SIDE

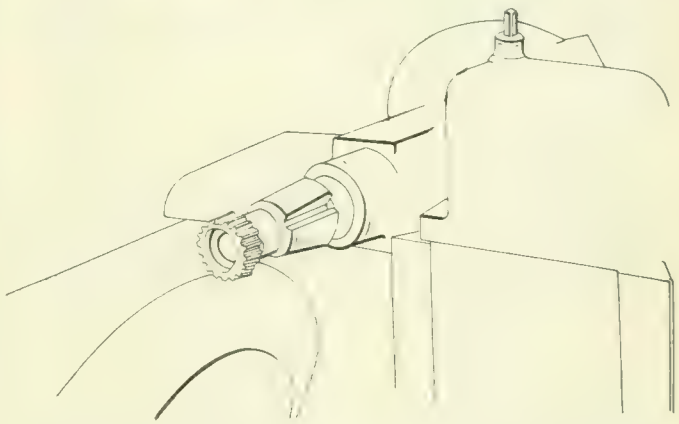


FIG. 11—THE SLOTTED LOCATING RING ON THE ARBOR FOR LOCATING THE GEAR IN THE PROPER RELATION TO THE GRINDING WHEEL

This allows an operator to run two or more machines simultaneously.

The carriage stops with the gear out of the wheel and to its right, so that the arbor can be loaded and unloaded without wheel interference. Of course, the gear must

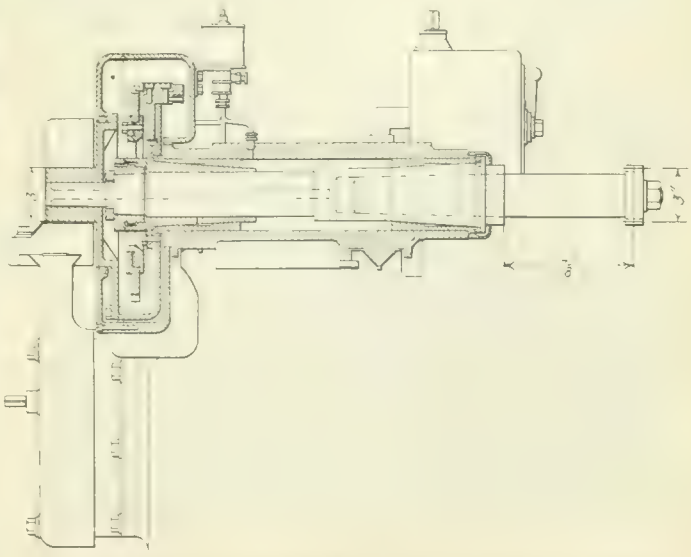


FIG. 12—CROSS-SECTION OF THE WORK SPINDLE, INDEX AND GENERATING MECHANISM

Fig. 10—Section of Work-Spindle, Table and Tape Bar

be located to mesh correctly with the grinding wheel and, to permit doing this quickly, a slotted locating-ring is attached to the arbor, as shown in Fig. 11. With a substantial knife-gage inserted in the ring-slot and between two teeth, the gear is positioned in proper relation with the wheel and the machine is then ready to start to grind again.

Application of the Generating Principle

Fig. 12 shows the work-spindle. It is taper journaled in bronze bearings, having flooded lubrication, and is mounted in a carriage which is driven with a drum-cam located in the bed. The generating principle of the work-spindle is accomplished by means of thin steel-tapes that wind and unwind on a pitch-diameter circle or segment as the carriage is driven forward and backward. This mechanism is at the rear of the work-spindle; it is shown in Fig. 13. There is practically no load whatever on these tapes; they simply oscillate the work-spindle and

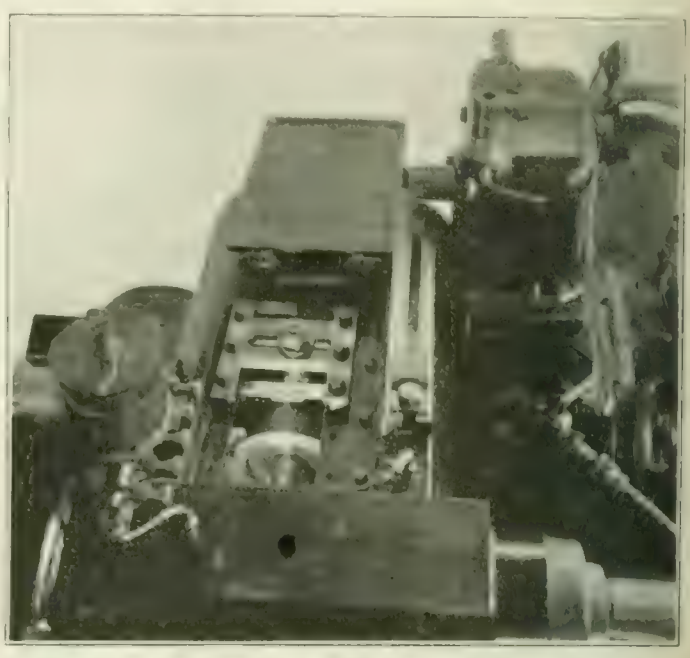


Fig. 14—Looking Down on the Top of the Machine with the Carriage Cover Open

The Drum-Cam, Carriage Drive and the Travel Adjustment Mechanism Can Be Seen

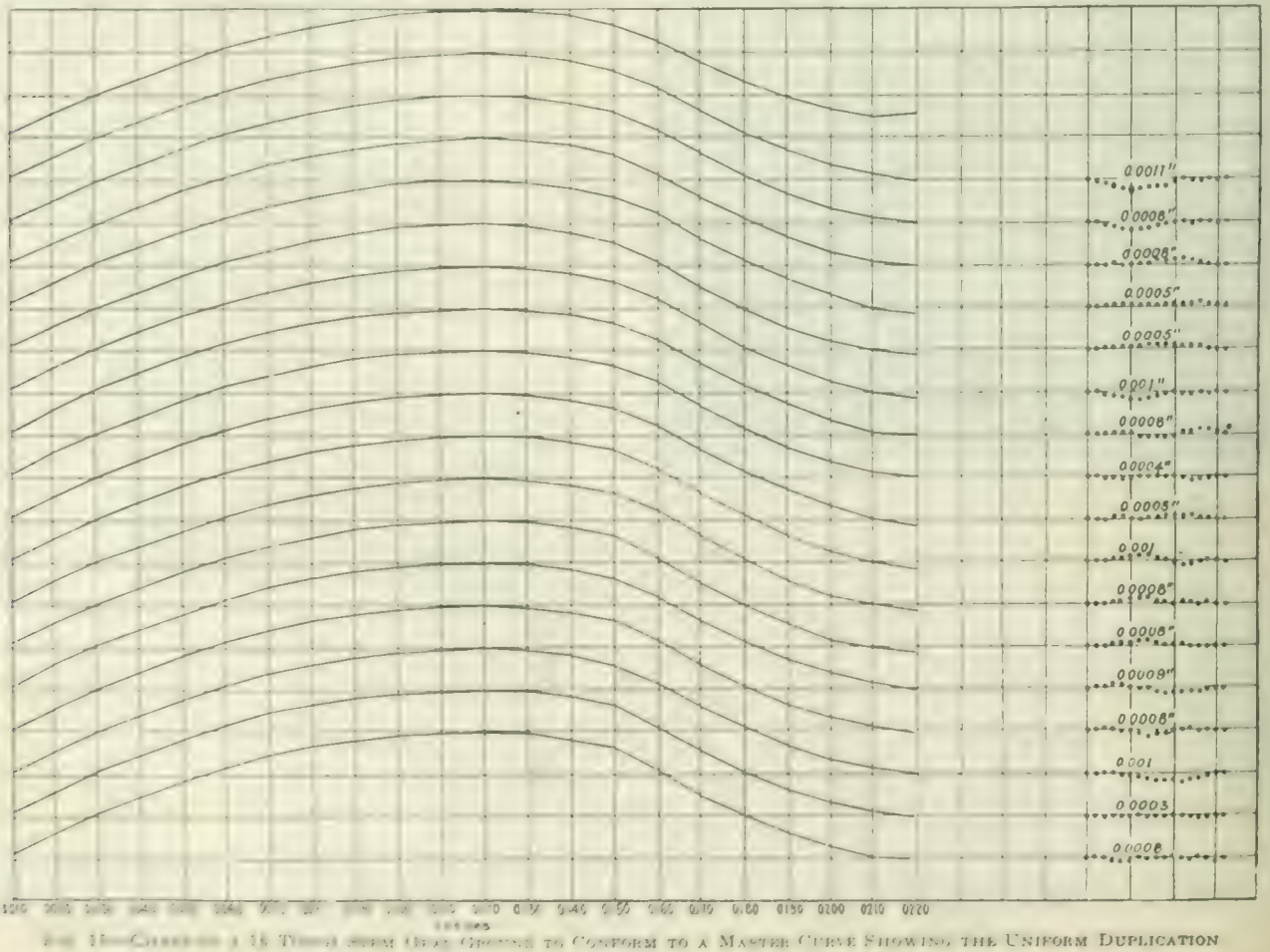


Fig. 15—Curves of 15 Tooth Helical Gear Grinds to Conform to a Master Curve Showing the Uniform Duplication

this enables the carriage to be driven at the same rate of speed on small pinions as on large gears. These tapes are 1¼ in. wide and only 0.008 in. thick, using one pair; that is, one end of one tape is attached to the segment and the other end to the tape-bar. The other tape is attached in a reverse manner, and screw adjustment is provided so that the tapes hug the segment snugly and produce uniform duplication of tooth-contour.

Indexing

The index mechanism is very simple; it, also, is at the rear of the work-spindle. Hardened and ground notched plates are used, having the same number of notches as the number of teeth on the gear to be ground. The notches are ground and lapped to very close limits to insure accuracy of tooth-spacing. It requires less than 1 sec. to index from tooth to tooth, and the grinding times vary according to the carriage change-gears used. We usually supply two pairs of change-gears to grind one side of the usual transmission-gear tooth in 5 or 6 sec., according to the accuracy, finish and amount of production desired.

Fig. 14 shows the carriage cover open and illustrates the drum-cam carriage-drive and the travel-adjustment mechanism. The cam-groove provides a smooth and suitable reversing drive, eliminating entirely load-and-

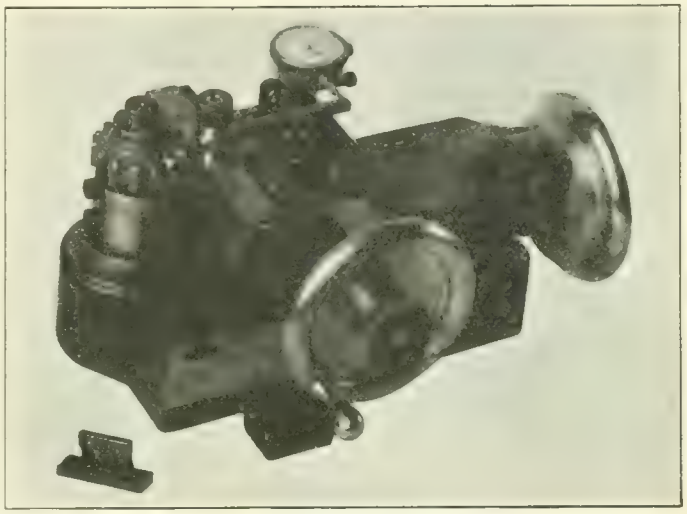


Fig. 16 Gear-Testing Device That Has Been Developed To Check the Involute Curve

left-hand end, to take care of pinion gears, and has holding studs and two slides at right angles.

Two methods can be used with this gear-tester. In starting to grind gears, good-rolling green-gears can be

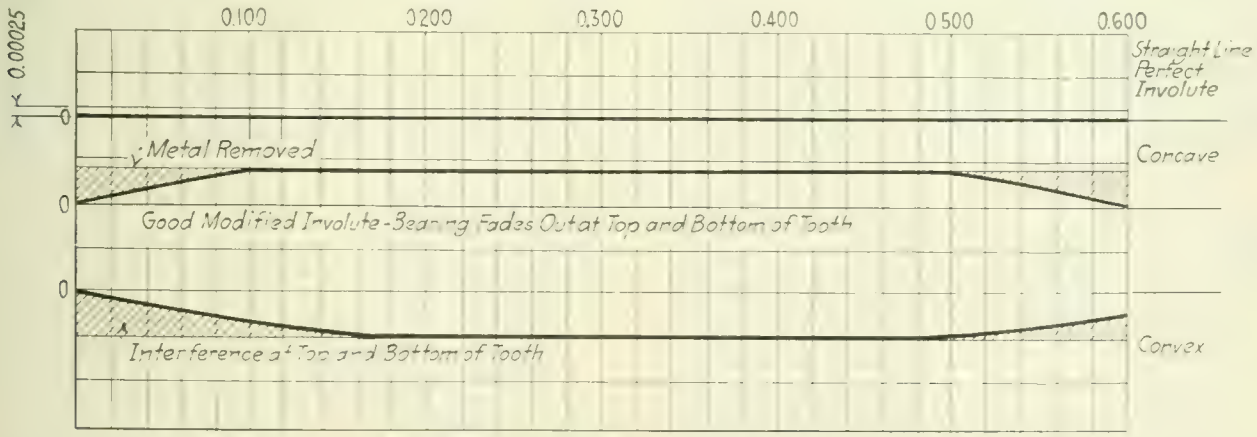


Fig. 17 —Chart Plotted by the Gear-Testing Device Showing the True Involute and Modified Curves

fire reverse-mechanisms, clutches and their attendant troubles. The stroke or travel of the carriage is adjustable to suit the pitch of the teeth; also, the position of the carriage in relation to the wheel is adjustable.

Fig. 15 is a chart of 16-tooth 6 to 8-pitch 14½-deg. P. A. stem-gears ground to conform to a master curve, the first curve shown in the illustration. This shows the uniform duplication of tooth-contour that can be ground with our machine at the high rate of 5 sec. per side of tooth. The finish was good and the tooth-spacing was as shown to the right, from readings taken over 4 teeth, or 90 deg. which, besides tooth-spacing, shows-up any eccentricity.

Gear-Testing Machine

Correct tooth-contour of the meshing gears and accurate spacing with a smooth grinding finish produce quiet running transmissions. Slight variations of tooth-contour can be made easily by giving more or less angle to the wheel, and also by varying the diameter of the pitch-circle or segment. We have developed a gear-tester, shown in Fig. 16, in order to measure these minute variations of tooth-contour, to know about the tooth-form and to be able to duplicate established tooth-forms. It consists of a base with a large ground bushing on the

picked out from production and tooth-curves can be charted by using the lower slide of this tester and then adjusting the grinder to duplicate these curves. The other method is to make base-circle adapter-studs, and

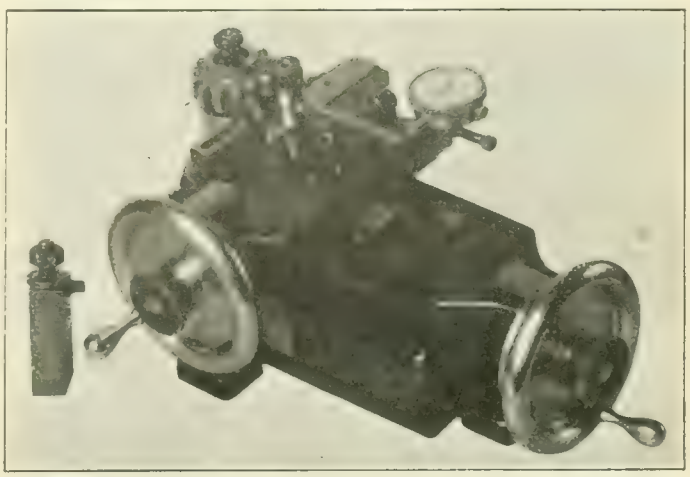


Fig. 18—Gear-Testing Device Arranged for Checking Tooth Spacing

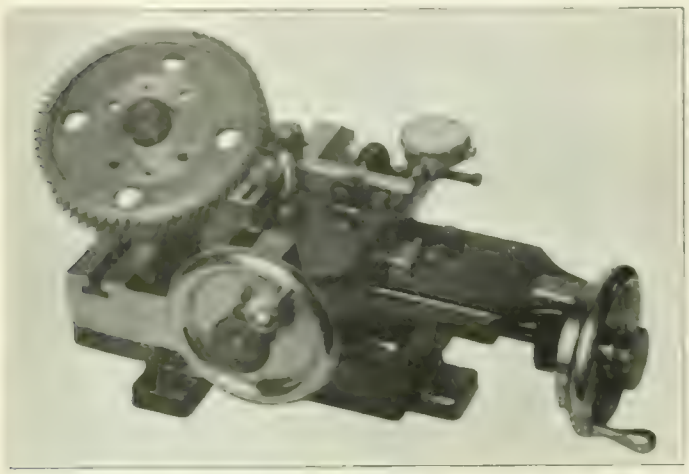


Fig. 17—Tooth-Testing Fixture Equipped with Special Adapters for Checking the Tooth-Contour and Spacing of Bevel Gears

these will give the variation of tooth-contour from the true involute. Two steel tapes are attached to the stud and the top slide; this insures correct indication without slippage on the smallest gears. If the tooth being tested is a true involute, the indicator will remain at zero and a chart can be plotted, using the hand-wheel graduations; a plunger automatically retards the hand-wheel every 0.010 in. The true involute tooth will show a straight line, as in Fig. 17. Modified curves are usually concave, that is, they fade out at the top and the bottom as shown in Fig. 17; if convex, there will be interference, as shown in the illustration.

Tooth-spacing can be tested either by direct reading, or with the post set at an angle of 90 deg. as shown in Fig. 18. The indicator needle can be reversed in cases where it is not possible to reverse the gear. By making special adapters, as shown in Fig. 19, engine-front spiral-gears, and also bevel-gears, can be checked for tooth-contour and tooth-spacing.

Summary

By using the machine and methods described, fine finishing cuts, burnishing and polishing operations can all be eliminated. Real economical production of transmission gears is attained by roughing-out the teeth to about a 0.005-in. oversize tooth-thickness, depending on the amount of backlash desired; then harden the gear, grind the hole or stem, and afterward grind the teeth. Why spend so much time with finishing operations and then subject the gears to heat-treatment? Even with the greatest of care, there is then some distortion. The finishing can be done best by grinding after hardening, and it can be done in about the same or even less time.

Just as all now agree with the plain cylindrical-grinder representatives, so now the teeth of transmission gears can be ground to established tooth-forms and limits and assembled interchangeably. The gears run quietly and stay in the transmission cases. There will be no more "tear-downs"; that is, so far as the gear teeth are concerned, provided, of course, the proper tooth-form has been adopted. Our system of developing, grinding and testing accomplishes this effectively.

WHEAT ACREAGE

The principal countries importing wheat are those of Western Europe and before the war an important share of their supplies came from Russia and the Balkan countries. Approximately 200,000,000 bu. annually were exported by these countries. These supplies were cut off in the first year of the war, with the result that the price of wheat rose rapidly in Western Europe and in all producing countries free to reach that market. Under this influence the acreage of wheat was enlarged, not only in the United States, but in other countries, and particularly in Canada, where a great opportunity for expansion existed in the Prairie Provinces.

The increased acreage and production of wheat in the United States and Canada under the stimulus of the war prices are shown by Table 1 which gives the average of each country in the 5 years preceding the war, the average for the 5 years 1914-1918, actual figures for 1919, 1920 and 1921, and the latest estimates for 1923.

TABLE 1—WHEAT ACREAGE AND PRODUCTION OF THE UNITED STATES AND CANADA

	United States		Canada	
	Acreage	Production	Acreage	Production
Average, 1909-1913	47,067,000	656,694,000	9,945,000	197,119,000
Average, 1914-1918	54,116,000	722,446,000	14,783,000	229,839,000
1919	75,064,000	967,377,000	19,125,000	193,260,000
1920	61,441,000	833,027,000	18,332,000	263,189,000
1921	60,208,000	791,894,000	23,261,000	300,858,000
1922	59,211,000	856,211,000	22,631,000	400,000,000
1923		700,000,000		383,000,000

It will be seen that the increase in Canadian production alone approximately equals the entire annual exports from Russia and the Balkan countries before the war.

The average production of the five leading export countries outside of Russia for the 5 years ended with 1913 and for 1922 is given in Table 2.

TABLE 2—WHEAT PRODUCTION IN THE LEADING COUNTRIES EXCLUSIVE OF RUSSIA

	Average, 1909-1913	1922
Argentina	157,347,000	215,320,000
Australia	84,943,000	105,000,000
Canada	197,119,000	400,000,000
India	349,919,000	366,352,000
United States	690,109,000	856,211,000
Totals	1,479,437,000	1,942,883,000
Increase	.....	463,446,000

This shows an increase in these countries of more than double the former exports of Russia and the Balkan countries. The average acreage in wheat in these five countries for the period of 1909-1913 was 108,682,000 acres; for the peak of the war period it was 141,626,000 acres; and for 1923 it was 136,795,000 acres.

It appears therefore that there is no mystery about the low price of wheat this year, especially when it is considered that the buying power of the importing countries has been below par, forcing them to resort to cheaper foods than wheat. Moreover, the situation as to wheat has been advertised as rather worse than the facts warranted. The carry-over in this Country has been exaggerated. The July reports of the Canadian crop represented one of 500,000,000 bu., and reports have been current that Russia might make indefinitely large exports. Under all this it is not strange that support for the market has been lacking. There has been no profit in carrying grain from harvest time to the end of the crop year in any year since 1920.—George E. Roberts in *Journal of American Bankers Association.*

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

FINISHING PISTON-RING GROOVES

A NUMBER of members have written the Research Department requesting information on the various practical methods of finishing piston-ring grooves to a very high degree of polish and accuracy. Attention is called to the fact that finishing with the ordinary forming-tool leaves a series of tool-marks or ridges that wear away initially very rapidly, thus creating an objectionable leakage space around the rings. Processes of grinding and lapping, which have been suggested, possess obvious disadvantages when considered from the point of view of production.

In an effort to obtain useful information on the subject, the Research Department communicated with leading manufacturers, a number of whom have outlined their methods for the benefit of others who may be interested.

The following extract is from a letter from a manufacturer who finds it possible to finish the grooves satisfactorily with suitable cutting tools:

> In our regular production we use the customary method of machining the grooves in the pistons, but to hold the grooves to size and get as smooth a finish as possible on the sides, we make a roughing and a finishing tool. By properly shaping the tool on the finishing cut we are able to secure a fairly smooth surface on the sides of the grooves. We also take considerable pains to keep the piston from moving endwise ever so slightly during this operation, as this produces wavy grooves and permits loss of power and leakage of oil.
>
> Some time ago we installed in an engine two pistons with the grooves very accurately tooled and polished. The remaining two pistons were of our standard production. We ran several tests to determine the ability of the two types of piston to hold compression, but were unable to ascertain whether the pistons with the polished grooves were superior to the others in this respect.

The forming tool is also found satisfactory by another automobile builder who writes:

> We find that an ordinary forming tool, when properly ground, is very satisfactory for this purpose. Some of the essential details are proper hardness of the tool, proper setting, point clearance, feed and speed and the condition of the piston iron. When these conditions are met a smooth and true groove should be the result.

No commercially satisfactory method of grinding piston-ring grooves seems to have been perfected. The experts of one of the foremost grinding companies brought out the fact that, even though it were possible with properly shaped wheels and present methods to grind the grooves very satisfactorily, yet it would be a toolroom job, not susceptible of easy adaptation to a production basis.

Perhaps the most promising methods offered for finishing grooves involve burnishing or rolling operations. One prominent company writes:

> The groove is first roughed out with a solid tool to approximately full depth and ⅛ in. wide. Then on another machine a second cut is taken which deepens the groove slightly and widens it to 5/32 in. This we hold to a tolerance of 0.01 in.
>
> On the same machine and with the back cross-slide the third cut is taken with split tools that do not cut at the bottom of the groove at all but simply shave the sides to a limit of from 0.1868 to 0.1878 in.; at least these are our gage limits but the piston grooves are actually made much closer than this.
>
> The fourth operation on the grooves is on a lathe where we run in a revolving burnishing disc that has sharp edges and is 0.1873 in. wide. This burnishes the sides of the groove and removes any ridges that might be left by the finishing tool.
>
> The final operation on the grooves consists of burring the corners and polishing the bottom with a narrow strip of emery cloth.
>
> In our opinion this method is as good as any unless we wish to go to a very expensive lapping operation. I believe also that the chief cause of wear between the ring and the groove is the roughness of the ring itself on the side. These rings are very hard and they are usually rather rough on the side from improper grinding and there is a filing action between the ring and the groove due to the fact that the ring is so much harder than the piston.
>
> It is now possible to lap the rings on the sides very economically and accurately, and we are considering doing this, as we will secure a flat, smooth, accurate ring that would certainly contribute greatly to longer wear.

A second company writes:

> The method followed in our factory for finishing piston-ring grooves is to burnish with hardened, ground and lapped high-speed steel rollers running in oil, set on a shaft in a holding fixture and used in a lathe. The rollers have a lateral movement to compensate for variation between grooves. The width of the rollers is about 0.0003 in. greater than the maximum width of the groove gage. The proper width of the rollers is controlled by the grade of cast iron in the pistons. The operation is short and is very satisfactory.

A third company states:

> So far our best results have been obtained from a burnishing roll or disc of approximately the same diameter as the piston, mounted on ball bearings and attached to the cross-slide of a lathe, burnishing one groove at a time. We are now equipping to try a combined skiving and burnishing operation.

Another factory uses a tool-holder carrying a series of hardened steel discs of the correct thickness, properly spaced to fit the piston-ring grooves. These discs burnish the metal on each side of the groove and have apparently proved successful.

Furthermore a motorcycle manufacturer reports as follows:

> We have done a great amount of experimenting in this direction, using a finishing roll about 5 in. in diameter made of carbon steel, ground and lapped to the proper width, and ground to produce very sharp corners. We found the roller would not work with

believe that good results may also be obtained by using regular chrome ball-steel.

A plant that has not found success with the above methods writes:

> We have done some experimental work in an attempt to improve our present method of finishing these grooves, principally with highly polished rolling-tools, and thus far have not been successful in improving at all on the method that we have always used. This method consists of making two cuts in the ring grooves, the first cut roughing them very close to size and the second cut taking a very fine finishing cut with a reasonably slow feed.

It is hoped that further material will be received from any of our readers who may care to offer it.

Important Sections Matters

Action Taken at Meeting of Council in Cleveland Relating to Non-Member Affiliation with Sections and Change in Dues

AT the meeting of the Council held in Cleveland, Oct. 24, several important decisions were reached with regard to Sections matters. A definite plan for the collection of dues of the Sections by the office of the Society, beginning with the next fiscal year, will be formulated for consideration at the meeting of the Council this month. A special committee was appointed to study thoroughly the relations of the local units of the Society to the parent organization, with the purpose of bringing about such reorganization and modernization as may be considered necessary or advisable. It is expected that this committee, in the work of which the Sections Committee will join, will hold hearings for a general discussion of the issues defined as to the basic principles in the providing of adequate local as well as national activities. The officers of all of the Sections will be fully informed as to the work being done by the committee from time to time.

Among the things to be studied is the reestablishment of a form of affiliation of non-members of the Society with the Sections, similar in principle to the enrollment of Section associates that was in effect several years ago but discontinued by Council direction. As stated elsewhere in this issue of THE JOURNAL, a demand has arisen in several Sections for such action, and the Sections Committee has been requested to draft an enabling provision for consideration in amending the standard Sections Constitution and By-Laws.

The subject of abolishing Sections dues as such and raising the amount of the annual dues of the Society to provide proper financial support for the maintenance of Sections activities to the extent of all reasonable demands is also before the committee.

OCTOBER COUNCIL MEETING

THE meeting of the Council held on Oct. 24 at Cleveland was attended by President Alden, Past-President Bachman, First Vice-President Crane, Second Vice-President Scarratt, Councilors Chryst, Gurney, Scaife, Scott and Sweet. J. H. Hunt, H. L. Pope and M. P. Ramsay, nominees for the 1924 Council, were also present.

The books of account for the fiscal year ended Sept. 30, 1923, are being audited by public accountants and it is expected that the unexpended income for the year will be over $17,000. A budget for the current fiscal year was approved in the sum of an estimated income of $275,000.

Applications for membership in the Society to the number of 87 were approved.

The following appointments to the Standards Committee were made:

R. E. Carlson—Lighting Division
Norman Conn—Iron and Steel Division
W. W. Davison—Axle and Wheels Division
W. J. Outcalt—Screw Threads Division
H. W. Sweet—Transmission Division

The next meeting of the Council will be held at Dayton on Nov. 20.

THE FARMER

TODAY the farmer's financial isolation is a thing of the past; special credit legislation has brought that about. Today the farmer's physical isolation is capable of very material modification; the telephone, the automobile, the radio have accomplished that. Today the farmer's political isolation is on the way to annihilation, the farmer's own aggressive action has achieved that. What we still need to accomplish is the wiping out of the farmer's social and mental isolation.

This last is not a problem peculiar to the farmer. It is something we must face and must answer in the case of every unit of our population. We must reduce, if not eliminate entirely, the isolation of ideas or ideals on the part of foreign-born, on the part of labor, on the part of farmers—yes, on the part of bankers. We must guard ourselves against the danger of isolation, of selfish consideration of our own interests exclusively or even primarily. We must all learn to function as partners in a common enterprise—the progressive development of our Country as an increasingly better place in which to live.—W. W. Head, Omaha National Bank.

The Standardization of Methods of Applying the Scleroscope

By A. F. Shore[1]

Production Meeting Paper *Illustrated with* Photographs and Charts

A STATEMENT is made of nine items suggested by the Iron and Steel Division of the Society for consideration with reference to securing greater uniformity in practice when making precision hardness-tests with the scleroscope. Plumbness of the instrument is an important factor and lateral vibrations have a bad effect; these are discussed and surface smoothness of the test-specimen is considered in relation to its effect on accuracy.

Other factors treated are the influence of metal-scale on scleroscope readings, the condition of the hammer diamond, and the effect of the mass of the test-specimen. Extreme under-weight specimens, inert and over-weight masses, the effect of hardness on mass and the effect of thickness of the test-specimen receive consideration, together with points concerning testing near test-specimen edges, the effect of curved surfaces and how test-specimens are held. A lengthy comparison between Brinell and scleroscope hardness-testing is made. The paper presents photographs and illustrative charts.

THE scleroscope has now been adopted so generally and is used under such varied conditions that a need has come to be felt for the greatest possible standardization of methods for its application. In addition to their regular instruction literature for this instrument, which is designed for the most universal application, its manufacturers have always maintained a department devoted to the study of special problems that have arisen relative to precision hardness-testing, particularly in quantity-production operations. However, they recognize the importance of securing more complete data relative to a better systematization of practice so that concordant results can be obtained more easily, independently, by everyone and under all conditions. To this end, the members of the Iron and Steel Division of the Society suggest the following items for consideration and treatment:

(1) Plumbness of the instrument at the time of hammer-drop
(2) Effect of lateral vibrations or shocks on the hammer
(3) Smoothness of surface of the test-specimen
(4) Condition of the diamond in the hammer
(5) Effect of mass on the test-specimen
(6) Thickness of the test-specimen
(7) Effect of testing near the edge of the test-specimen
(8) Effect of curved surfaces of test-specimens
(9) How test-specimens are held or mounted

[1] M.S.A.E.—President, Shore Instrument & Mfg. Co., Jamaica, N. Y.

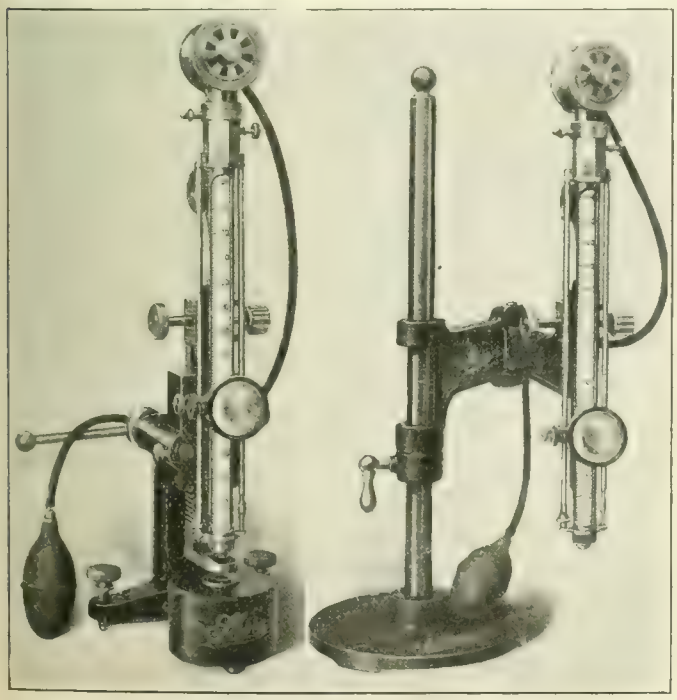


Fig. 1—Two Views of the Vertical Scale Scleroscope

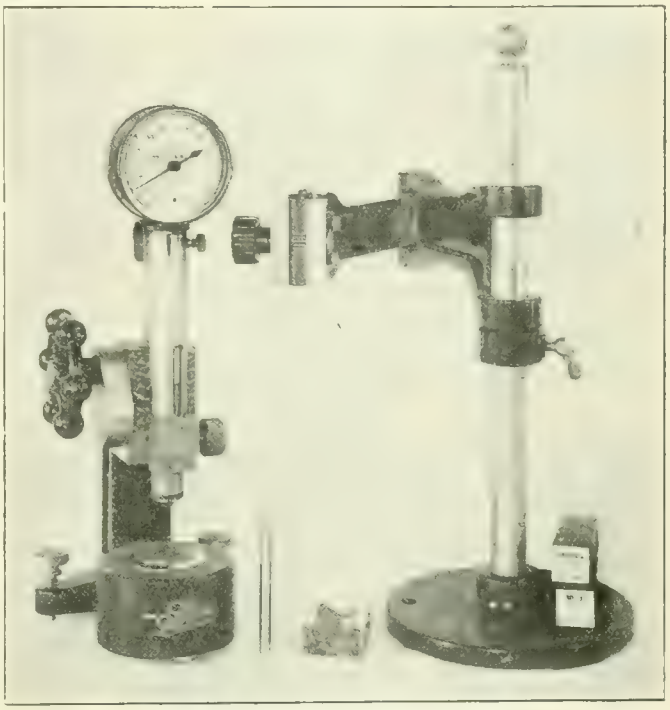


Fig. 2—The Recording Scleroscope

Plumbness of the Instrument

Manufacturers' instructions to users always have been to set or hold the scleroscope as perfectly plumb as possible. The deviation should remain within 1 deg. The instrument will then indicate with 100 per cent accuracy. Notwithstanding this advice, it is of importance to know

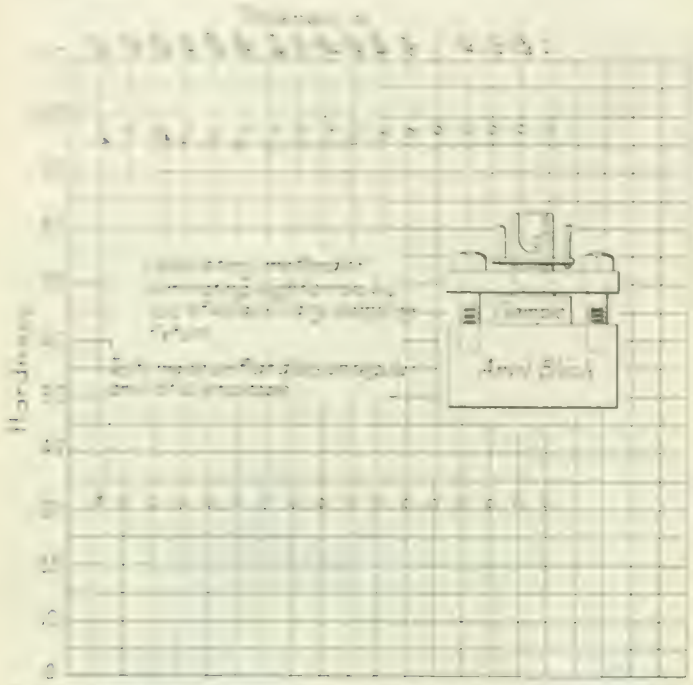


FIG. 3—SCLEROSCOPE HARDNESS TESTS MADE ON DISCS MEASURING 1⅜ IN. IN DIAMETER AND OF DIFFERENT THICKNESSES

just how much of a drop in readings would occur for each degree that the instrument may be out-of-plumb and this would be of material guidance to operators. If the surface of the test-specimen is also tilted or remains at right angles, the drop in readings thus approximates about 0.007 per cent on the scleroscope scale for each degree of angle for the first 5 deg. At 10 deg. of angle, the total drop in readings is about 8 per cent. The objection to holding the instrument out-of-plumb is not only the drop, but the fluctuation in the readings so caused. When the instrument is permitted to be out-of-plumb, but the surface of the test-specimen is level, the errors on both hard and soft metal are proportionately greater because of the glancing blow struck. Table 1 shows the errors for deviations of 1 to 5 deg., and for 10 deg.

TABLE 1—SCLEROSCOPE ERRORS FOR VERTICAL DEVIATION

Deviation from Vertical. Deg.	Loss, Per Cent
1	1.0
2	2.5
3	4.5
4	7.0
5	10.0
10	33.0

A deviation from the vertical of as much as 2 deg. is easily noticeable to the unaided eye; 3 deg. is decidedly noticeable. Both the Model-C vertical-scale scleroscope shown in Fig. 1 and the Model-D recording scleroscope shown in Fig. 2 are affected equally under the conditions just cited.

Effect of Lateral Vibrations

It is understood that, in the test made for deviations from plumbness, both types of instrument were held steady or free from lateral movement or shocks. When either type of scleroscope is moved or shaken roughly enough to rattle the plumb-rod, it has a marked effect upon the accuracy and uniformity of the instrument's indications, because of the effect on the drop-hammer. These conditions must be observed when free-hand tests are made.

Surface Smoothness of the Test-Specimen

Having the surface of the test-specimen too rough causes a drop in the readings, but not so much as usually is supposed. The principal objection to rough surfaces in scleroscope practice is the fluctuations thus caused in the readings. These are more misleading than the percentage of drop in the readings.

If a test-specimen of flat hardened-steel about 1½ in. wide shows a reading on the scale of 100 hard on a comparatively smooth surface, and this surface is then ground on the side of a rough but true emery-wheel 14 in. in diameter and tested again, the reading will fall to and fluctuate from 94 to 98 on the scale. If the same surface is ground on a disc machine faced with No. 2½ paper having No. 60 emery, the readings will fall and fluctuate from 97 to 99. When further smoothed with No. 20 French paper having No. 120 emery and the surface is not polished, the instrument shows a reading of 100 very uniformly. No increase in readings is obtainable by further polishing.

On soft steel that shows a reading of 32 hard when polished, by using the same coarse-emery stone, a reading of only 29 to 31 is obtained, and this is a drop of 9.3 per cent and 3.1 per cent in the readings. Using the same No. 2½ paper having No. 60 emery, a reading of 29 to 32 is obtained. The effect of using smoother papers, until practically a mirror finish is obtained, is not to increase the reading, namely, 32, but to reduce the variations to zero.

On metal that can be filed, the maximum readings are obtained by the use of a flat crossed-cut file having about 70 teeth per in. If the teeth are not crossed-cut, a file having about 50 teeth per in. will make the surface smooth enough.

Influence of Scale on Metals

Experience has demonstrated that the scale on steels in the soft condition influences the scleroscope readings

only slightly. Therefore, it is feasible to select the high-carbon steels from the low-carbon steels taken from a pile of mixed bars, the identity of which has been lost. The condition necessary for making determinations under these circumstances is that the test be made where the scale is as smooth as possible, or free from blisters or rust. When the steel is hardened, it also can be tested through the scale by making allowance for a small loss or drop in the readings. Here, too, it is important that the scale be dry and also free from rust. Two or three tests should be made because of the unfavorable surface conditions, and the results should be averaged.

The Condition of the Hammer Diamond

The condition of the diamond in the scleroscope drop-hammer of both the Model-C vertical-scale and the Model-D dial-recorder instruments is determined regularly by making a few tests on standard reference blocks which accompany each testing unit. If they check-up properly, the diamond is considered to be perfect. If it reads low, particularly on the hard reference-block, it is because the point either has become roughened or has worn more pointed. These diamonds are not polished, but they are reasonably smooth and observation through a magnifying glass will disclose whether or not their failure to check properly with the standard blocks is due to the condition of the diamond or to some other cause.

In this connection, many are calling for special checking-blocks having a hardness that compares as nearly as possible with that of a particular run of parts which are made in quantity. This will serve to reduce uncertainties in inter-practices to a minimum.

Effect of Mass of the Test-Specimen

Some users still suppose that, in measuring hardness with the scleroscope, the accuracy of the results on small test-specimens depends directly upon the mass of the test-specimens and that, as this mass is increased, the readings also become higher. To a certain extent, this would be true if the specimens of metal to be tested were suspended in the air or mounted on an anvil or base of some light yielding substance such as wood or rubber. However, since it is just as easy to use the steel anvil with which all scleroscopes are provided, all the following tests to be discussed will be considered to have been made on a steel anvil inserted in an iron base heavy enough to resist the shocks of the drop-hammer, or the equivalent, the anvil on all special holding devices. When the test-specimens are supported properly in this manner, it is found that variations in their mass amount to so little that accurate measurements can be obtained easily and uniformly. In the technique of mounting or clamping, particularly for complex specimens, it is none the less important to understand the several basic interfering factors that may enter.

This subject already has been treated in Chapter 12 of an instruction booklet entitled The Effect of Mass on Rebound, that accompanies each scleroscope testing-set; therefore, it is thought that the main interest at this time centers in charts that show curves of the results. The data were obtained on under-weight specimens of varied sizes and shapes used in actual practice; in the laboratory for absolute accuracy, and in the shop under production methods such that the principal object sought is uniformity and speed, but which readings may depart slightly from the laboratory results and for which the indicated allowances would then need to be made.

Results thus obtained from testing small flat specimens

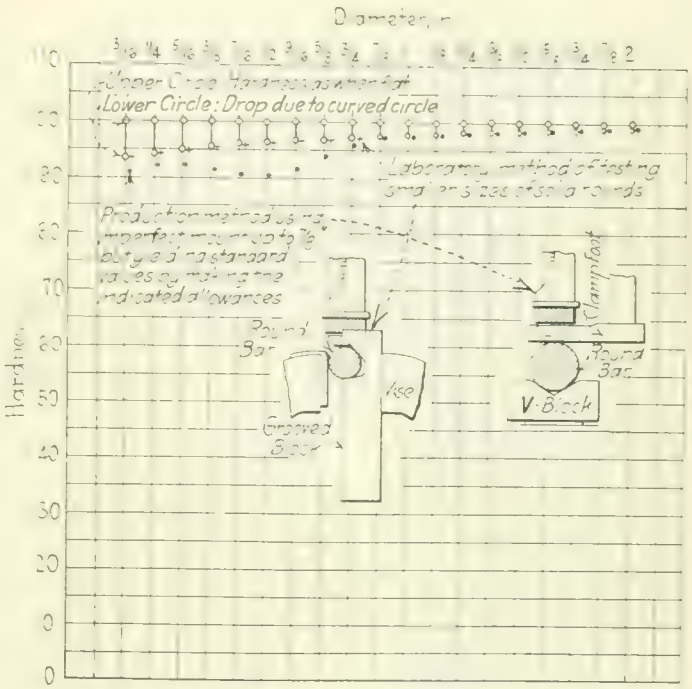


Fig. 5.—Results of Hardness Tests Made with the Vertical Scale Scleroscope on Hardened Cylindrical Pieces of Different Diameters

that are not especially prepared with reference to flatness and smoothness but, rather, which have commercially ground surfaces and are clamped in the portable stand of the Model-C scleroscope, are shown in the curve of open dots in Fig. 3, and for the Model-D recording scleroscope in Fig. 4. The corrections on hardened samples by having the specimens ground smoother so as to lie perfectly flat and thus eliminate air space and dust, when clamped in the regular stand, are shown in the curve that is constituted of small crosses. This latter curve also applies to the special clamping-down fixtures in Figs. 3 and 4, and when using the scleroscope on its clamping

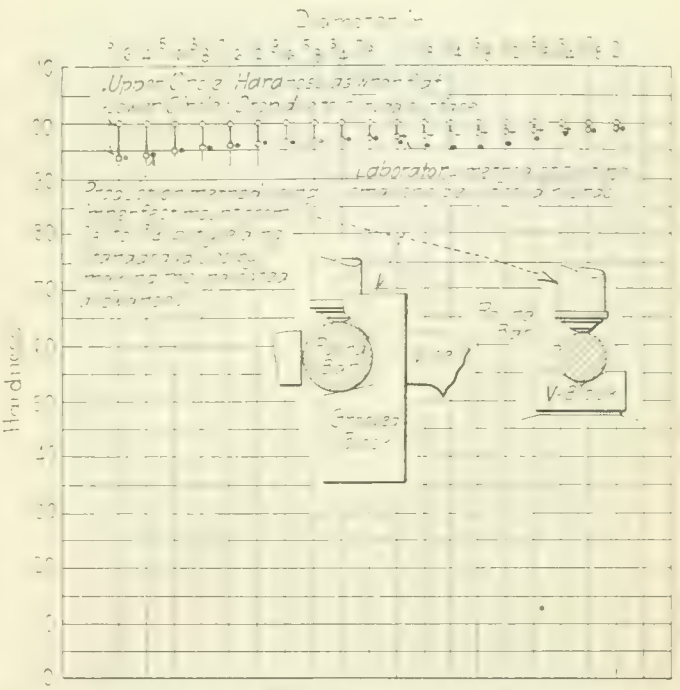
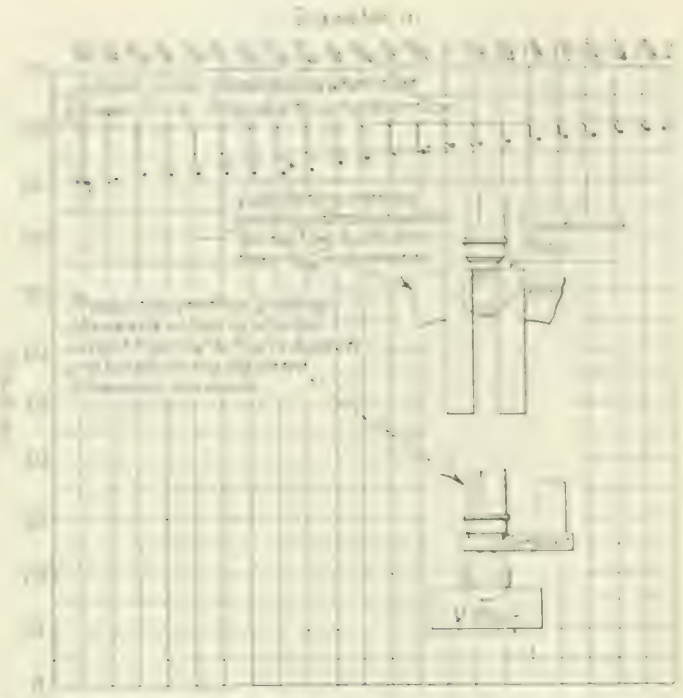
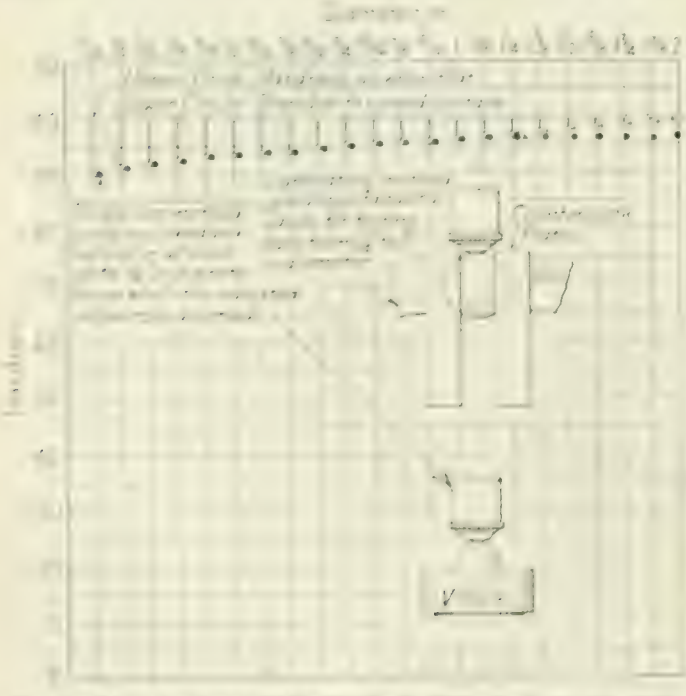


Fig. 6—Results of Another Series of Hardness Tests Made with the Recording Scleroscope on Hardened Cylindrical Pieces of Different Diameters



stand or when resting on a bench plate with the instrument on its swing-arm.

For small round specimens, the test results obtained are shown in Fig. 5 for the Model-C scleroscope and in Fig. 6 for the Model-D recording scleroscope. It will be seen that by merely using a V-block without making special provisions for obtaining precise laboratory results, the size is an interfering factor; (*a*) because of lack of proper under-support and (*b*) due to the lack of mass. The results obtained when using the V-block method of support, which is used for production purposes, are shown in the solid dot curves. The correct values, as obtained by clamping the specimen in a grooved block in the bench vise, are shown in curves of small crosses. In the curve that is made up of the small circles the still further corrected values obtained by making allowances for the curvature of the test surface are shown.



Figs. 7 and 8 show the results obtained on hardened steel balls for the Model-C and Model-D instruments respectively. Here also, the solid dot curves stand for values obtained in a circular V-block in the clamping stand. As a support, it is only approximately correct, but it serves the purpose well for rapid production purposes, particularly in centralizing the ball. For precise values, a recessed pair of blocks having a hardness of about 70 was used for clamping the balls in a bench vise, shown in the insert. The curve of small crosses shows the resulting values; and the curve of the small circles shows the increase due to stoning the series of balls flat, or the allowances regularly to be made for the curvature of test surfaces.

Figs. 9 and 10 show tabulated test results that were obtained on case-hardened and soft hollow piston-pins, for Model-C and Model-D instruments respectively. The curves of the solid dots show values obtained on hollow piston-pins in both the soft and the hardened condition when supported in a V-block, and without using a plug on the inside. The thickness of the wall of the series of sizes given was one-sixth of the diameter of the pin. Other pins were tried that had a thickness of wall of one-eighth and of one-tenth the diameter of the pin without departing materially from this curve. A more correct curve indicated by small oblique crosses is shown also; it was obtained by clamping the unplugged hollow pin in a bench vise provided with a well fitting split-block. A still better method is to plug the hollow pin and to test either on the V-block or in the split-block in the bench vise, and this will give absolute-standard laboratory-values. In production practice, the unplugged hollow pin is tested in the V-block, and the indicated allowances are made, including the drop in readings due to curvature of the test surface. In this manner many thousands of tests can be made per day.

Extreme Under-Weights

Under-weight samples such as sheets, thin flats, small balls, rods or wire, that can be made to lie flat immediately under the drop-hammer of the scleroscope, will show 100-per cent normal results without clamping them down. The reason is that the weight and impact of the drop-hammer serve to accomplish the clamping without the use of any other means. However, in standard practice, the clamping down of all under-weight samples is necessary, regardless of the size of the piece, to make certain that no air space or intervention of dirt may cause variations in the accuracy of the indications.

As the mass of the test-specimen increases, particularly if it is hardened, and assuming that it is *not* clamped down, when struck by the scleroscope drop-hammer it will be driven down to its supporting base or anvil to form a better contact, and will have a tendency to rebound of itself. This, theoretically, should cause interference with the indications of the drop-hammer. Thus, when the test-specimen is of such a size as to offer the greatest interference, say in the ratio of about 8 or 9 to 1 of the weight of the hammer, it can be said to have a relative critical weight. Then, the precaution of clamping is most necessary.

Inert and Over-Weight Masses

Inert and over-weight masses can be defined as specimens that are approximately in the ratio of more than

25 to 1 of the weight of the drop-hammer. These masses depend less on the anvil for their under-support and are also too inert to react or interfere with the rebound of the hammer. Comparatively, these specimens are easier to mount for obtaining precision results and, if larger, they usually are placed without clamping on an iron bench-plate when tested.

Effect of Hardness on Mass

In the smaller softer metal specimens, the under-support must be the same as for those of hardened steel, but the downward pressure of the clamping means is of less importance, because of the more complete absorption of the shock of the hammer and the decrease of the tendency of the test-specimen to react against the hammer.

Thickness of the Test-Specimen

With the Model-C vertical-scale and with the Model-D dial-recorder scleroscopes, sheets of hardened steel and of the soft metals can be tested down to paper thickness or foils.

In hardened steel, a single specimen that measures less than 0.005 in. in thickness can be tested accurately. In the softer metals, specimens that are of extreme thinness must be piled-up to attain a thickness of 1/50 to 1/32 in., according to the increase of softness. These tests must be made in scleroscope clamping-stands for flats and sheets, as indicated at the left in Figs. 1 and 2. The mass contained in flat specimens, because of the flat anvil-support obtainable in the soft and in the hard condition, has very little influence on the results under either the Model-C or the Model-D scleroscope; this is indicated in Figs. 3 and 4. If the anvil support is very poor, due to lack of flatness of the test-specimen, the mass of the *entire specimen*, if it is of large area, does not necessarily have an influence on the results but, rather, *it is the mass immediately under the drop-hammer*, and extending radially to a diameter of between five and six times the thickness. The flat specimens used for preparing Figs. 3 and 4 were circular in form, 1⅜ in. in diameter and hardened. Other flats of the same form and series of thicknesses were tested, up to a diameter of 2½ in., and this resulted in a slightly greater correction in the curve of open dots in Fig. 3. When there is considerable lack of smoothness or flatness of plates or flat specimens of hardened steel that have small thickness, and there is doubt that the universal scleroscope is showing the exact value, the samples can be soldered to a larger block of metal and compared with the regular readings, or they can be screw-clamped down with a greater pressure in a holding fixture as shown at the right in Figs. 3 and 4. Another method that provides similar corrective qualities and also is adapted to accommodate tapered pieces, is the rocker flat-anvil illustrated in Fig. 11. It is especially recommended for the Model-C scleroscope.

Testing Near Specimen Edges

On small parallel or flat specimens, little or no difference is noted by testing near the edges if the specimens are clamped properly. On other shapes, such as cylindrical specimens, particularly when these are hollow as in the case of piston-pins, a certain amount of drop in the readings is noted, due to the lack of mass and to improper under-support. However, these errors can be corrected readily on divers shaped pieces by the use of suitable clamping devices as shown in Figs. 3 to 10.

Effect of Curved Surfaces

Curved surfaces can be divided into two classes, rounds

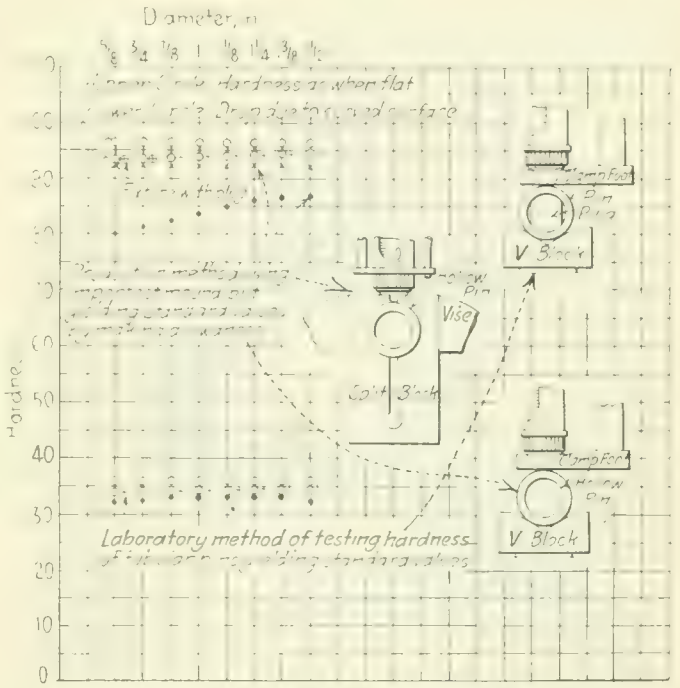


Fig. 9—Results of a Series of Tests Made on Tubular Piston-Pins with the Vertical Scale Scleroscope

or cylindrical surfaces and spherical surfaces. The effect and allowances to be made for the curvature of rounds of hardened steel are illustrated clearly in Figs. 5 and 6. The effect and allowances to be made on spheres or small balls of hardened steel are illustrated in Figs. 7 and 8. These standardized allowances naturally apply to specimens of other cross-sections such as hollow rods, as in Figs. 9 and 10, or to other specimens having similar spherical surfaces that are to be tested. As the hardness runs lower in the scale on all metals, the effect of the curvature is proportionately less. For example, if, in a hardened steel ball that is 100 hard and 13/16 in. in diameter, there is a drop of 5 deg., equal to 5 per cent, in the

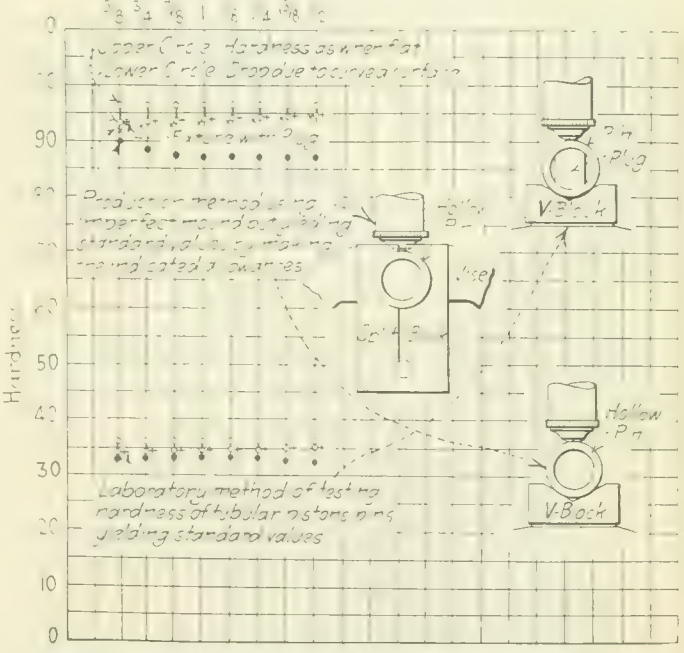


Fig. 10—Results of Another Series of Tests Made on Tubular Piston-Pins with the Recording Scleroscope

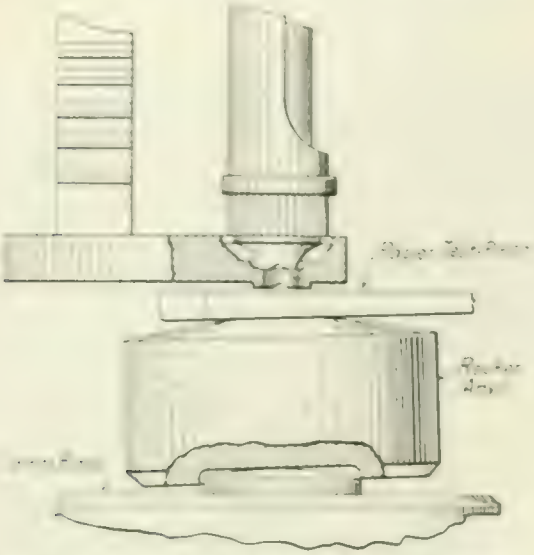


FIG. 11—HARDENED FLAT-ANVIL THAT IS RECOMMENDED FOR USE WITH THE VERTICAL-SCALE SCLEROSCOPE WHEN TESTING CUTTING TOOLS

readings, at a reading of 50 hard, the drop in the readings is still 5 per cent or 2½ deg.

How Test-Specimens Are Held

Unlike other machines for testing the hardness of metals, the scleroscope obtains its indenting force from the fall of its rebounding hammer. Therefore, the specimens can be of unlimited size and the instrument does its work by merely setting it on top of the specimens to be tested. Of the forms not referred to in the illustrations, small reamers and drills can be tested accurately with the Model-D scleroscope in its regular clamping-stand. For reamers, a V-block or a round-grooved block can be used; but drills must be placed on the flat anvil to be tested on the side. If drills are to be tested in quantity, a suitable guide can be attached for holding each size central with the drop-hammer. For testing reamers and drills under the Model-C vertical-scale scleroscope, a split-block fixture in the bench vise is used, as shown by the curves of small oblique crosses in Figs. 9 and 10. These blocks are recommended also for testing these tools under the Model-D scleroscope.

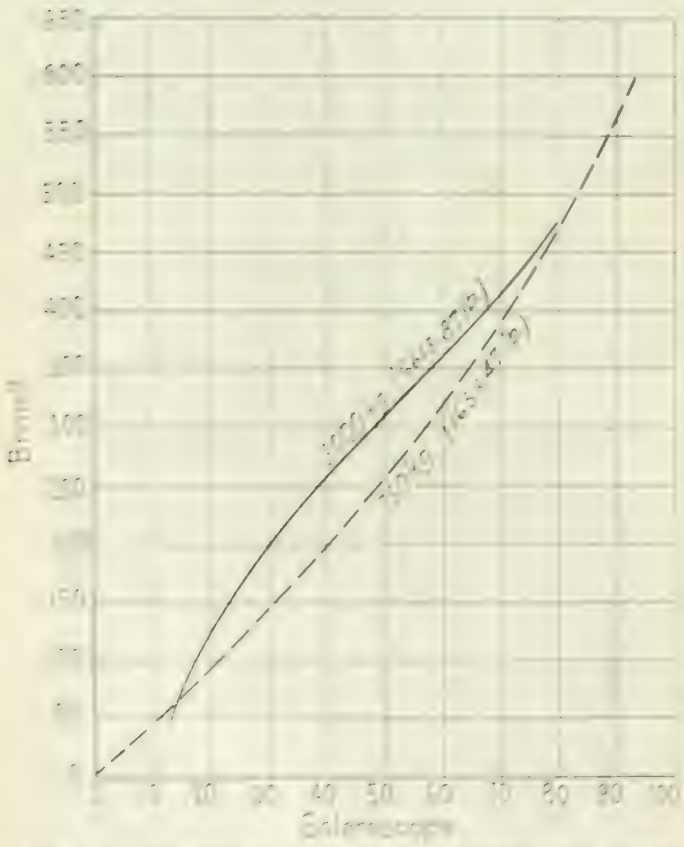


FIG. 12—RELATION BETWEEN THE BRINELL BALL-TEST AND THE SCLEROSCOPE-HARDNESS TESTS OF A BAR OF SOFT STEEL, USING A 10-MM. (0.394-IN.) BALL AND THE STANDARD DIAMOND-TIPPED HAMMER

Brinell and Scleroscope-Hardness Comparisons

In the course of our experience, for a number of years, we have been called upon many times to provide the latest data showing the relation between the values of the ball test and those of the scleroscope. It has always been believed that the Brinell ball-test shows values that bear a relation to the ultimate tension resistance of a metal, while the scleroscope, as we have always claimed and which can be demonstrated, shows a definite relation to the elastic-limit under both tension and transverse stresses.

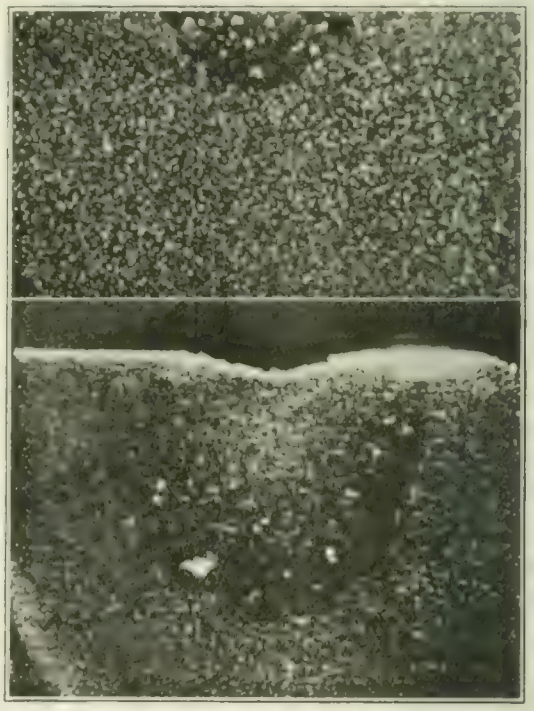


FIG. 13—MICROGRAPHS SHOWING THE DEPTH OF THE STRESS IN THE SELECTED CRYSTALS OF A PIECE OF SOFT STEEL SUBJECTED TO THE BALL TEST

The Upper View Is a Vertical Section of the Bottom of the Depression Made by a Ball That Was Subjected to a Pressure of 100 Kg. (220.462 Lb.) and the Lower View Is a Similar Section when the Pressure on the Ball Was 3000 Kg. (6613.87 Lb.) The Steel Test-Piece Had Been Annealed at a Temperature of 1500 Deg. Cent. (2732 Deg. Fahr.) for Hr. Before the Test Was Made. The Magnification in Each Case Is 6 Diameters

Pursuant to an invitation from Sir Robert Hadfield, I submitted a paper to the Iron and Steel Institute, of London, England, in September, 1918, entitled Relation Between Ball Hardness and Scleroscope Hardness. This treated the subject rather exhaustively. This article was never published and discussed extensively in this Country, and some of its leading features are repeated.

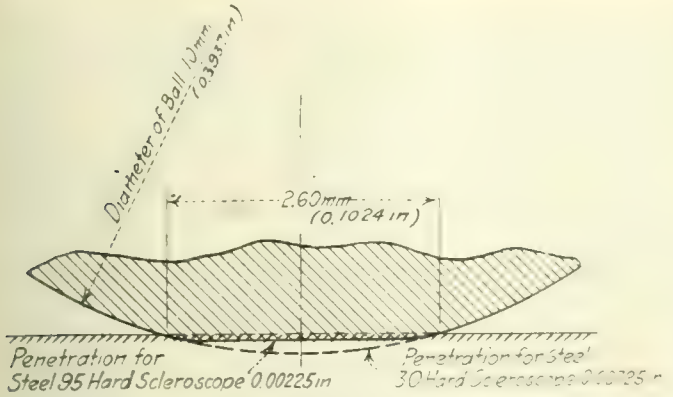

Diameter of Ball 10mm (0.3937 in)
2.60mm (0.1024 in)
Penetration for Steel 95 Hard Scleroscope 0.00225in
Penetration for Steel 30 Hard Scleroscope

FIG. 14—HOW THE BRINELL STEEL BALL BECOMES FLATTENED WHEN FORCED AGAINST A PIECE OF HARDENED STEEL UNDER A PRESSURE OF 3000 KG. (6613.87 LB.) AND THE MEASURED DEPTH OF PENETRATION FOR THE SAME DIAMETER OF IMPRESSION IN SOFT STEEL

Its principal feature was the conversion chart shown in Fig. 12, from which it is evident that, when a pressure of 500 to 750 kg. is used on a 10-mm. ball in the Brinell machine, a consistent and satisfactory relation with the scleroscope values can be obtained. On the other hand, the full-line curve shows that, by the use of a pressure of 3000 kg., a comparatively irregular curve is obtained, and the agreement with the scleroscope values is comparatively unsatisfactory. In seeking an explanation for the irregularity of the 3000-kg. curve, it was acknowledged to be due to three causes; (*a*) in the lower portion, to the flow of the metal under excessive indenting pressure; (*b*) in the middle portion, to metal flow and super-hardening; and (*c*) in the upper portion, to flattening of the steel ball. The effect of the two respective pressures as developed by Stead's annealing treatment, which indicates the depth of the strain on the structural crystals, is shown in the metallographs, Fig. 14. The flattening of the steel ball on a test-specimen 98 hard by the scleroscope is shown in Fig. 15.

To eliminate the third difficulty (*c*) a superior diamond insert is used in the universal scleroscope drop-hammer which enables it to overcome the resistance of the hardest steel with complete success under many thousands of tests. Hence, in order that the Brinell values might be compared with full accuracy on hardened steels, a ball fashioned from a similar diamond was used on all specimens above 75-hard by the scleroscope. In using this diamond ball, it is not safe to use a load greater than 750 kg. Under this pressure usually only one to three tests can be made; then failure occurs. Under a load of 500 kg. the diamond ball may make from 6 to 12 tests before failing.

Further reference to Fig. 12 will disclose a considerably higher relative value in the 3000-kg. line than in the dotted 750-kg. line, particularly in the steel group between the annealed condition and that of spring temper. Referring to Fig. 16, it would appear that, since the scleroscope symbolizes the tension resistance at the elastic-limit in metals having some toughness, and the ball test agrees very closely with these values when a pressure of 500 to 750 kg. is used on a 10-mm. ball, the higher pressure curve that shows higher hardness-numbers demonstrates that the Brinell test so applied indicates an additional value, namely, that of the ultimate tensile-strength. More recent researches indicate, however, that these higher figures do not, necessarily, represent values beyond the elastic-limit or that they lean toward the ultimate tensile-strength. In fact, in the light of present knowledge, ultimate-tensile-strength values probably cannot be symbolized as the result of one simple test that is so entirely opposite in nature as the one for resistance to compression or physical hardness.

In the group of more ductile steels, it is well known that the ultimate-strength is commonly 100 per cent greater than the elastic-limit, when they are subjected to tensile strain. If we make a ball hardness-test in two stages, such as 500 kg. against 3000 kg. and then let the difference in the calculated values stand for ultimate-strength symbols, we find that an increase, usually, of less than 25 per cent in the hardness readings is obtainable under the higher pressure; whereas, as before stated, it should be nearly 100 per cent.

Further investigations will show that the significance of the calculated hardness-increments under the higher pressures are almost entirely negatived insofar as they may symbolize ultimate-strength, for the reason that comparatively brittle cast-iron is even more apt to show these than the ductile steels. In view of this fact, it is apparent not only that a pressure of 3000 kg. for ball testing is superfluous, but that the resulting values do not really symbolize ultimate-strength and, in general, are misleading.

Therefore, in order that the two recognized hardness-values may be related to meet the general demands, it would seem that the pressure advisable is one that does not exceed 1000 kg. on a 10-mm. ball and with a decrement in several stages, ending in about 25 or 50 kg. for soft lead. The object of this is to eliminate or reduce to a minimum the flow in any of the metals subjected to

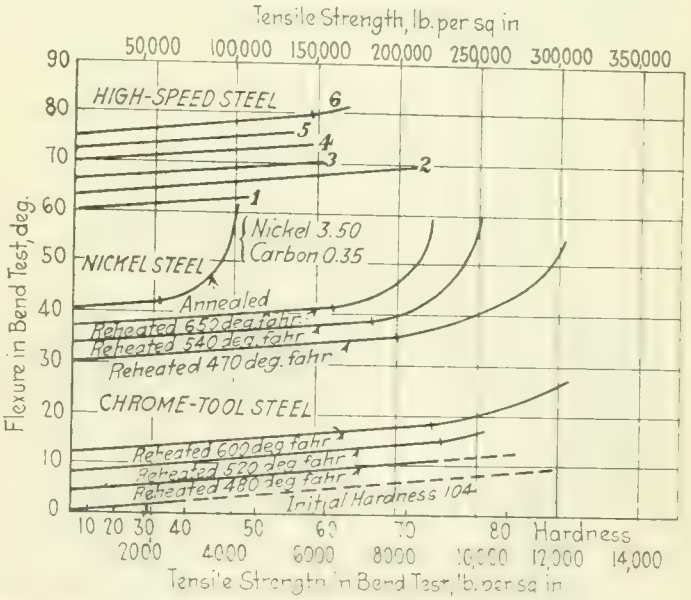


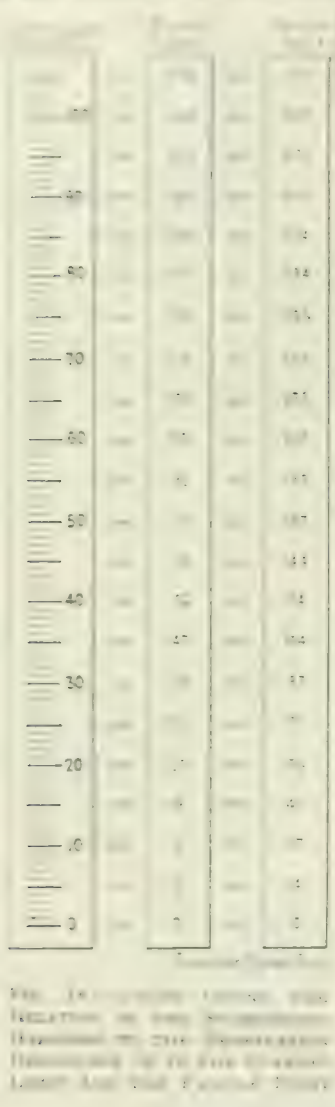
FIG. 16—CHART SHOWING THE RELATION BETWEEN THE HARDNESS AND THE TENSILE-STRENGTH UP TO THE ELASTIC-LIMIT AND THE RELATIVE STRENGTH AND HARDNESS OF CANTILEVER BEND-TEST SPECIMENS HAVING A LENGTH OF 6 TO 1 OF CROSS-SECTION AT THE POINT WHERE THE LOAD WAS APPLIED

The Heat Treatment for the Various High-Speed Steels Is Given in the Following Table:

Steel No.	Hardening Temperature, Deg. Fahr.	Cooling Medium	Hardness
1	2,250	Kerosene	99
2	Rolling Heat	Air	101
3	2,150	Kerosene	95(*a*)
4	2,000	Air	84(*a*)
5	2,150	Air	99
6	2,100	Air	90

(*a*) These steels were tempered at 650 deg. fahr.

the hardness test. By thus modifying these misleading factors the time factor becomes such a negligible quantity that static and kinetic classes of tests are rendered



more closely comparable. In fact, the less the metal is damaged, the less is the amount of cold-working and under-hardening that follows; so, the resulting indicated values are more faithfully representative of the true and original resistance to compression or indentation which really constitutes the true definition of quantitative hardness. Through the medium of the scleroscope test and for the entire range of metals, making only a slight allowance for the softer non-ferrous alloys in which a certain amount of injury occurs under the drop-hammer of the universal instrument, resistance to penetration in pounds or tons per square inch up to the elastic-limit can be symbolized to a degree of remarkable precision. Likewise, the incipient and marked-failure point can be indicated as by allowing a predetermined amount of permanent set, or penetration.

These relative values are shown in the two comparative tables in Fig. 13. In the preparation of these figures a flat punch under static pressure was used on a flat surface with an allowance of enough margin in the specimen to avoid lateral expansion or possible rupture. The reason is that the compressive resistance per unit of area on such a surface is somewhat greater than it is on a column of the same area as the punch, due to shear resistance of the surrounding uncompressed areas. The guiding influence for the designer and the general serviceability of a properly standardized hardness-test are demonstrated by the rapid failure of the samples as a result of the addition of but slightly more load than that called for in the immunity, or elastic-limit column, of Fig. 13. These values, in tons per square inch, are 45 per cent of those given in the marked-failure-point column. If, instead of this 45 per cent, 50 per cent of the loads indicated in the marked-failure column is applied, immunity ceases and an injury, detectable under a microscope, occurs in the entire range of metals. The amount of set or depression allowed in the marked-failure-point column varies according to the hardness. In steel that is 100-hard, it is about 0.0005 in. In steel that is 50-hard, it is from 0.0010 to 0.0015 in. The depth increases down to the softest metals, in which it is about 0.0150 in. Although the hardness test is one that necessarily is applied to a surface larger than the area under stress, the shear resistance being added, a notable instance in which the hardness test symbolized the columnar resistance only is found in the universal use during the world war of the scleroscope, in this Country and abroad, on steel shells, to determine their resistance to buckling on account of the concussion of the firing charge.

THE UNPARALLELED VOLUME OF FREIGHT TRAFFIC

UPON what a vast scale production of all kinds has been proceeding in the United States since the beginning of 1923 is well illustrated by the fact that, according to reports filed by the railroads of the country with the car service division of the American Railway Association, no less than 6,181,744 freight cars were loaded with revenue freight during the first 44 weeks of the year. This was not only the largest number of cars loaded with revenue freight in any corresponding period in the history of the railroads, but was an increase of 5,564,042 cars, or 20 per cent, over the loadings for the same weeks in 1922. Of the total number for the period this year 19,421,008 cars were loaded with merchandise and miscellaneous freight, an increase of 1,847,808 cars, or nearly 11 per cent, compared with the first 8 months in 1922.

Loadings of grain and grain products in the 8-months' period this year totaled 1,454,744 cars, a decrease of 122,872 cars, or nearly 8 per cent, from the loadings of the same months last year. Live stock loadings, however, totaled 1,119,840 cars, which was an increase of 120,975 cars, or 12 per cent over the figure for the corresponding period 1 year ago.—*Economic World.*

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

BOAT STANDARDS NEEDED

Motorboat Division Initiates Comprehensive Program of Standardization

The Motorboat Division held its initial meeting of the year on Sept. 27 and, in accordance with the consensus of opinion that a real need of standardization in the motorboat industry existed and that a determined effort should be made toward developing standards, it was decided that monthly meetings should be held until the work shall be well under way. A second meeting was therefore held on Oct. 25. Both of the meetings were at New York City as this is the most centrally located city for the Division members.

At the September meeting Charles M. Manly, vice-chairman of the Standards Committee of the Society, acted as chairman. It was decided that engine standardization should be considered by the Engine Division of the Standards Committee with the exception of such matters as are peculiar to motorboat applications. To determine upon a feasible as well as a logical program, the Division devoted both meetings to a general discussion of possible subjects, dividing them into the following general classifications:

General
Hull
Joiner Work
Fittings, Hull and Deck
Rudder and Steering-Gear
Engine, Installation and Equipment
Lighting
Ventilation
Heating
Plumbing
Bilge Drainage
Equipment, Communication and Rigging

It was recognized that it would be better for the Division to select only the most important subjects that could be put into practice without too much resistance, leaving the more difficult subjects until the standardization work shall be well under way.

The Standards Department, to make the work of the Division as effective as possible, was instructed to keep all motorboat builders in close touch with the work of the Division.

BALLOON TIRES DISCUSSED

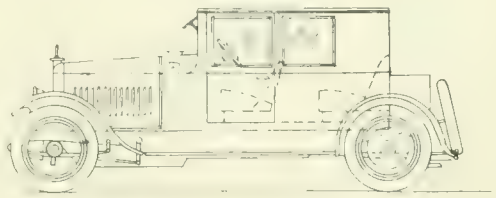
Balloon tire development was discussed at the September meeting of the Tire and Rim Division with special reference to the desirability of having the automobile builders participate in establishing definite standards. The Division went on record as being in favor of establishing suitable standards for balloon tires and rims at an early date to avoid the variety of sizes that would otherwise be developed by the different tire and automobile companies working independently.

It was proposed that arrangements should be made looking toward the holding of a general conference, at which representatives of the Rubber Association of America, the Tire and Rim Association of America, the Tire and Rim Division of the Society's Standards Committee and the National Automobile Chamber of Commerce should discuss standardization possibilities comprehensively.

"COACH" APPROVED AS BODY TYPE

Passenger-Car Body Division Recommends Inclusion in Standard Body Nomenclature

At the meeting of the Passenger-Car Body Division in September, it was proposed to extend the present standard nomenclature for passenger-car body types to include the "coach" type of body. Although the desirability of recommending the use of this name, which has been popularized during recent years was discussed at some length, it was found impossible to suggest a better name that would be descriptive of the type of body in mind. The accompanying definition and illustration were approved by the Division for publication in the S. A. E. HANDBOOK under Automobile Nomenclature, Division XVIII, Types of Body, provided such action shall be approved by the Society in accordance with its usual standardization procedure.



Coach.—An enclosed single-compartment body, similar in general appearance to the sedan, with two close-coupled cross-seats for four passengers. There is a luggage compartment or space for a trunk at the back of the body. There is no glass in the rear quarters. The conventional type has two doors only, the forward seats being divided and the right-hand seat tipping forward to give access to the rear cross-seat. Some models have two doors on the right-hand side, there being two fixed cross-seats.

TESTING HEAD-LAMP VOLTAGE

Special Committee Appointed to Determine Uniform Method

A special Subdivision was appointed by Chairman McKay at the September meeting of the Lighting Division to formulate a uniform method of testing head-lamp voltage as well as to cooperate in securing data on existing practice. J. H. Hunt, of the General Motors Research Corporation, was appointed chairman, the other members being C. A. Atherton, A. L. Lewellen, P. R. Moffett, O. W. A. Oetting, L. C. Porter and Herman Schwarze.

The appointment of the committee was the result of the attention that the Lighting Division members have given to the high-voltage conditions that obtain in the lighting cir-

ALUMINUM SHEET SIZES PROPOSED

Passenger-Car Body Division Considers 12 Satisfactory for General Application

Although the present S. A. E. Non-Ferrous Metals Specifications cover specifications for aluminum sheet and strip, with respect to both chemical and physical properties, no attempt has been made hitherto to standardize on a limited number of sheet sizes.

Appreciating that the body industry would gain through the elimination of many odd sizes of sheet, the Passenger-Car Body Division at its September meeting decided to recommend the adoption of 12 sheet sizes for general body applications. The sizes proposed are given in the accompanying table.

ALUMINUM SHEET SIZES PROPOSED AS STANDARD

No. 14 Gage	*No. 16 Gage*
24 x 72 in.	24 x 72 in.
30 x 96 in.	30 x 96 in.
36 x 120 in.	36 x 120 in.
36 x 144 in.	36 x 144 in.
48 x 144 in.	48 x 144 in.
60 x 120 in.	.....
60 x 144 in.	.....

The recommendation does not include any sheet of No. 15 gage because the demand for sheets of this thickness is not large relatively. It is recognized that the list of sizes proposed does not cover general practice entirely, but the sizes recommended are considered adequate for future production needs.

It was appreciated that the large producers of automobile bodies will not use always the sizes recommended, owing to the fact that a special size is often warranted if purchased in large quantities. But it is considered that the smaller body producers will adhere to the proposed standard very advantageously. The Division recommended that the following footnotes be included as part of its recommendation.

A polishing sheet of No. 14 gage may be obtained in thicknesses Nos. 4 and 6. Sheet of No. 16 gage can be obtained in temper No. 6 only.

"Commercial" or "bright finish" product is finished in polishing rolls.

Gray plate is not finished in finishing rolls and is not recommended for stamping.

As the sizes proposed by the Division are now carried in stock by the manufacturers, the recommendation of the Division will not result in making it necessary to carry additional sizes in stock while the standard sizes are being put into practice.

SCREW-THREADS REPORT APPROVED

Society to Act on Sectional Committee Report on Screw-Threads at Annual Meeting

At the meeting of the Screw-Thread Division in September it was recommended that the report of the Sectional Committee on the Standardization and Unification of Screw-Threads should be approved by the Society as a joint sponsor.

The Sectional Committee on the Standardization and Unification of Screw-Threads was organized under the regulations of the American Engineering Standards Committee to review the report of the National Screw Thread Commission, on which the American Society of Mechanical Engineers and the Society of Automotive Engineers are the two civilian participating organizations, with a view of establishing a definite report which could be adopted as an American Standard. In accordance with the rules and regulations of the American Engineering Standards Committee, the report of the Sectional Committee must be approved by the sponsor organizations, the American Society of Mechanical Engineers and the Society of Automotive Engineers, before it can be acted upon by the Main Committee of the American Engineering Standards Committee. The American Society of Mechanical Engineers has already approved the report of the Sectional Committee and, as a result of the action of the Screw-Threads Division, the matter of approval by the Society of Automotive Engineers will be brought up for action at the Annual Meeting of the Society.

Inasmuch as the report of the Sectional Committee covers classes and fits that are not used in the automotive industry, such as the loose-fit class for screws with the neutral zone definitely placed, the Screw-Threads Division will recommend at the Standards Committee meeting certain parts of the Sectional Committee Report for adoption as S. A. E. Standard. The Society members will therefore have available in the S. A. E. HANDBOOK all screw-thread data applicable to automotive engineering.

It is recognized that the Sectional Committee Report does not cover all possible screw-thread applications, but is intended primarily for fastening units such as screws, bolts, studs and nuts. The Screw-Threads Division is therefore working concurrently with the National Screw Threads Commission in developing a recommendation for tolerances for lengths of engagement up to 3 in.

REVISED ALUMINUM STANDARD PROPOSED

Non-Ferrous Metals Division Proposes Revision of S.A.E. Specification No. 78

The Non-Ferrous Metals Division is considering a revision of the present specification for aluminum sheet and strip printed on p. D121 of the S. A. E. HANDBOOK, as proposed by Chairman Jeffries. The principal change suggested is the specifying of four instead of three tempers. The present specification revised as proposed follow:

SPECIFICATION NO. 78 ALUMINUM SHEET AND STRIP

Composition in Percentage.—Aluminum, min., 99.00.

Physical Properties.—Aluminum sheet or strip is furnished in several tempers or degrees of hardness. These tempers or degrees of hardness are indicated by the reduction in thickness produced by cold-rolling after annealing and are expressed in terms of the number of American-wire-gage sizes included between the original and final thicknesses. Thus, "Temper No. 4" indicates that the thickness of the sheet or strip after annealing was 4 gage-numbers more in thickness, having been reduced to size by cold-rolling. "Temper No. 0" indicates that the sheet or strip is in the soft annealed state. "Hard temper" indicates that the sheet or strip has been reduced in thickness after annealing by 12 or more gage-numbers. The mechanical properties of aluminum sheet or strip of tempers Nos. 0, 4 and 6 and hard temper are given in the accompanying table.

The tensile test-specimen shall be cut from the sheet or strip parallel to the direction of rolling. The bend test-specimen may be cut without regard to the direction of rolling. Sheet or strip of tempers Nos. 0 and 4 shall withstand being bent-cold flat upon itself, with-

out cracking. Although tensile tests of sheet or strip of temper No. 6 indicate an elongation only slightly greater than that of the hard temper sheet, it is considerably more ductile, as is evidenced by the fact that it will withstand cold-bending through an angle of 180 deg. around a diameter equal to twice the thickness of the sheet, without cracking. Hard aluminum sheet or strip will not endure any considerable amount of bending without cracking, especially in the thicker gages.

PHYSICAL PROPERTIES OF ALUMINUM SHEET AND STRIP

Temper	Thickness A.w.g. From	A.w.g. To, Incl.	In. From	In. To, Incl.	Minimum Tensile Strength, Lb. per Sq. In.	Minimum Elongation in 2 In., Per Cent
0 (Soft)	2	9	0.258	0.114	12,000	30
	9	16	0.114	0.051	12,000	30
	16	20	0.051	0.032	12,000	25
	20	24	0.032	0.020	12,000	20
	24	28	0.020	0.013	12,000	15
4	6	9	0.162	0.114	16,000	7
	9	16	0.114	0.051	16,000	7
	16	20	0.051	0.032	16,000	5
	20	24	0.032	0.020	16,000	4
	24	28	0.020	0.013	16,000	3
6	10	16	0.102	0.051	18,000	5
	16	20	0.051	0.032	18,000	3
	20	24	0.032	0.020	18,000	2
	24	28	0.020	0.013	18,000	2
Hard	10	16	0.102	0.051	22,000	4
	16	20	0.051	0.032	24,000	3
	20	24	0.032	0.020	26,000	2
	24	28	0.020	0.013	30,000	1

PERMISSIBLE TOLERANCES

Thickness A.w.g. From	A.w.g. To, Incl.	In. From	In. To, Incl.	Permissible Tolerance, Plus or Minus, In.
2	4	0.258	0.204	0.010
4	9	0.204	0.114	0.006
9	13	0.114	0.072	0.003
13	21	0.072	0.029	0.0025
21	24	0.029	0.020	0.002
24	28	0.020	0.013	0.0015

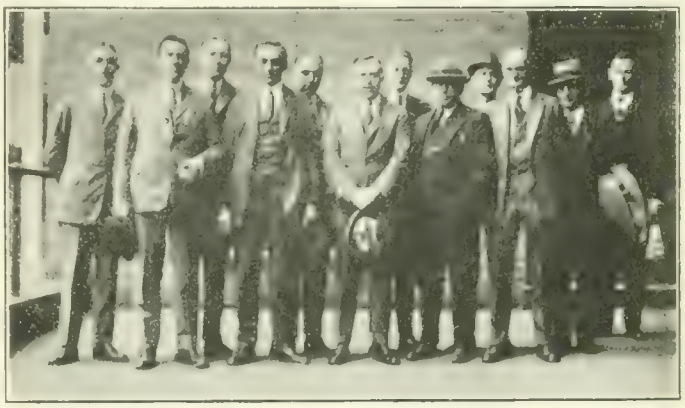
General Information—The specific gravity of aluminum sheet and strip is about 2.70. Young's modulus of elasticity is about 10,000,000 lb. per sq. in. Aluminum sheet or strip is used for many purposes where the requirements either as to service or as to the forming operations are too specific to be covered in any general specification. It is usually advisable therefore to submit samples or drawings to the manufacturer to assist in the selection of the proper temper for the service or forming operations.

Aluminum sheet or strip is used for automobile bodies, hoods (special flat sheet), fenders, housings, floor coverings, molding, instrument parts, instrument-boards, hub-caps, wire-wheel discs, brake-drum covers, miscellaneous pressings, and for many parts used in aircraft construction

BRAKE-LINING TESTS DISCUSSED

Improved Machines Developed by Brake-Lining Subdivision Members

At the meeting of the Brake-Lining Subdivision held in New York City on Oct. 9, the recent work of the Division members in determining suitable tests for brake-lining was discussed in detail. Clarence Carson, chairman of the Subdivision, submitted blueprints of a machine that he had designed recently as a result of his experience with a brake-lining testing-machine similar to the one developed by S. von Ammon at the Bureau of Standards, which was described in detail in the paper presented by the latter, entitled Developing a Method for Testing Brake-Linings, at the 1922 Annual Meeting of the Society.



Members of the Brake-Lining Subdivision Who Attended the Meeting Held at New York City on Oct. 9

Mr. von Ammon described another testing-machine that had been developed at the Bureau of Standards as a result of experience with the original machine developed there. Although these new testing machines differ somewhat as to principles of construction, it is felt that the results obtained from them would be of considerable value.

Articles describing the new testing machines will be included in early issues of The Journal.

Those present at the meeting were Clarence Carson of Dodge Bros., S. von Ammon of the Bureau of Standards, H. R. Cobleigh of the National Automobile Chamber of Commerce, J. Driscoll of H. W. Johns-Manville Co., C. E. Harwood of the Russell Mfg. Co., W. S. James of the Bureau of Standards, W. H. Morris of the Keasbey & Mattison Co., C. F. Ogren and W. D. Pardoe of the Thermoid Rubber Co., R. H. Soulis of the Multibestos Co., H. R. Wolf of the General Motors Research Corporation and Standards Manager R. S. Burnett.

REVISED TIRE-STANDARDS PROPOSED

Tire and Rim Division Cooperating with Tire and Rim Association of America

On Sept. 27 the members of the Tire and Rim Division held a meeting in Cleveland at which the existing S. A. E. Standards and Recommended Practices for tires and rims were reviewed and definite revisions suggested. All the members of the Division, which consists of J. G. Vincent, chairman; B. B. Bachman, A. J. Scaife and H. M. Crane, were present with the exception of Mr. Crane. Alex Taub of the General Motors Corporation, G. L. Lavery of the Tire and Rim Association of America, C. B. Whittelsey, chairman of the Tire and Rim Division for several years, General Manager Clarkson and Standards Manager Burnett were also present. The Division, which is working closely with the Tire and Rim Association of America and the Rubber Association of America, will submit definite recommendations covering the proposed revisions at the Annual Meeting of the Standards Committee. As the tire and rim standards in Section G of the S. A. E. Handbook have not been revised for several years, the action taken, which is outlined hereinafter, will be of special interest.

Pneumatic Tires and Rims

With the addition of the 31 x 4-in. regular tire and rim size, the proposal of the 1922 Tire and Rim Division was considered to provide a suitable range for practically all passenger-car requirements. A recommendation was therefore made that the present S. A. E. Standard for Pneumatic

Tire and Rim, p. G1 of the S. A. E. Handbook, be revised to conform to the revised proposal of the 1922 Division. The present standard, revised as proposed by the Division, is given in the accompanying table.

STANDARD SIZES OF PNEUMATIC TIRES AND RIMS

Type	Nominal Size		Normal Rim		Tolerance Dimension A
	Size	Type	Number	Diameter	
Balloon Tires		C		31x4	
		"		31x4	
		"	11x4		
		"	12x4		
		"	12x4½		
		"	13x4½		
Motorcycle Tires		"			
		"			
		"			
		"			
		"			

[illegible]

Pneumatic-Tire Rim Sections

Since it was felt that the detailed rim dimensions are not of special interest to the Society members, it was proposed that the present S. A. E. Standard for Pneumatic Tire and Rim Sections, p. G2 of the S. A. E. Handbook, should be revised in accordance with the present standards of the Tire and Rim Association and reprinted as general information only.

Pneumatic-Tire Felloe-Bands

As it was considered that the scope of the Tire and Rim Division should include only tire and rim matters, it was proposed that the S. A. E. Standard for Pneumatic-Tire Felloe-Bands, p. G4, should be withdrawn and further action in the connection referred to the Axle and Wheels Division.

Rim Clamp-Bolts

It was noted that the numbers of bolts specified for the various sizes of rim were not in accord with present practice, and in view of the action taken on pneumatic-tire felloe-bands the matter of revising this standard was also referred to the Axle and Wheels Division.

Solid Tires

It was proposed that the present S. A. E. Standard for Solid Tires, p. G10, should be brought into conformity with the solid-tire standard of the Rubber Association of America.

Solid Tire Base-Bands

Similar action in reference to the S. A. E. Standard for Solid Tire Base-Bands, p. G11, was taken.

Carrying Capacities and Inflation-Pressures of Pneumatic Tires

Since the S. A. E. Standard for Carrying Capacities and Inflation Pressures of Pneumatic Tires, p. G6, is primarily of interest to the tire manufacturers, being intended to regulate operating conditions, it was proposed that the present standard should be withdrawn and the table of carrying capacities and inflation-pressures adopted by the Tire and Rim Association published as general information only in Section G of the S. A. E. Handbook as the standard of that association.

Deflection and Set Test for Pneumatic-Tire Rims

As the S. A. E. Standard for Deflection and Set Test for Pneumatic-Tire Rims, p. G6, is intended for use only by the rim manufacturers, the Division recommended that the standard should be withdrawn.

Felloe Bands

In accordance with the action limiting the scope of the Division's work to tire and rim matters, work relating to modification of the present S. A. E. Standard for Felloe-Bands, p. G7, was referred to the Axle and Wheels Division.

Wood Felloes for Pneumatic-Tire Rims

The subject of revising the present S. A. E. Standard for Wood Felloes for Pneumatic-Tire Rims, p. G8, was also referred to the Axle and Wheels Division. It was noted that a similar specification for steel felloes would be of value to the industry.

Motorcycle CC Rims

In conformity with the action taken on pneumatic-tire rim sections, it was proposed that the present S. A. E. Recommended Practice for Motorcycle CC Rims, p. G9, should be revised to harmonize with the specifications of the Tire and Rim Association of America, and reprinted in Section G as general information only, with reference to the recommendations of the Tire and Rim Association of America.

Motorcycle Tires

The Division recommended that the present S. A. E. Recommended Practice for Motorcycle Tires, p. G9, be brought into agreement with the corresponding standard of the Tire and Rim Association of America and proposed for adoption as S. A. E. Standard, if this shall be satisfactory to the motorcycle manufacturers.

Solid-Tire Felloe-Bands

The matter of further consideration of the standard for Solid-Tire Felloe-Bands, p. G12, was referred to the Axle and Wheels Division.

Solid-Tire Demountable Rims

As the present S. A. E. Recommended Practice for Solid-Tire Demountable Rims, p. G14, is obsolete, it having been continued in recent years owing to the fact that some special equipment was still made in accordance with this standard, it was proposed that it should be withdrawn.

Industrial-Truck Tires

No new action was taken on the S. A. E. Standard for Industrial Truck Tires, p. G16. It was suggested that a conference be held with the Rubber Association of America as to the commercial status of this standard.

GERMAN BANK FUNDS

The [illegible] German banks, including savings institutions, at the end of 1922 were estimated at about 3,000,000,000 gold marks as compared with 8,500,000,000 gold marks [illegible] and some 20,000,000,000 gold marks of foreign credit [illegible] in 1913. The decline in deposits of banks expressed in gold marks corresponds to the general policy of German business men to keep with banks only an amount sufficient for their liquid funds in paper marks and to convert the rest into foreign exchange, real estate or other tangible assets whose value is not affected by the depreciation of the mark. The increase in deposits with banks abroad, coupled with the decline in paper mark holdings, clearly indicates the general policy of banks and commercial houses to emancipate themselves from the paper mark and to convert their assets into values not subject to depreciation.—*Economic World.*

MEETINGS OF THE SOCIETY

BRAKE DESIGN AND CONSTRUCTION

H. M. Crane Presents Fundamental Principles at Metropolitan Section Session

A bumper meeting of the Metropolitan Section was held on Oct. 18, well over 200 persons being present. Henry M. Crane, in a paper that is printed elsewhere in this issue of THE JOURNAL, presented facts that he considered of importance in connection with brake design, his observations being the result of nearly a score of years of experience. He presented a curve showing that the braking effect of the engine is greater when the throttle is closed. The condition he referred to was one in which the throttle was really closed, and in which the switching-off of the ignition would not increase the braking effect.

H. M. CRANE

Mr. Crane stated as the crux of the whole brake question the securing of the result desired most directly and with the least mechanism. He exhibited drawings that showed the principles of practice he described. He also showed a fabric type of band that was glazed rather than worn after 60,000 miles of service in a transmission brake of a passenger-car that was not run at high speed and with which the engine was used in high-gear as a brake. The brake was oiled from time to time, this making its action smoother and keeping the binder of the fabric in good condition. Mr. Crane stated that this band was probably good for 50,000 miles of additional service.

In the discussion, A. L. Clayden said that in the case of brakes, as of most other components of cars, the principal thing is the merit of the design and the construction. A simple design gives the best results. The tendency has been toward a complicated structure. He expressed the opinion that no one place on a car is better than another from which to retard the motion of the car. The principal difference in the condition with four-wheel brakes is that there is more braking area.

Chairman Cornelius T. Myers expressed the view that brakes have been a weak element and that the agitation in connection with four-wheel brakes will result in the improvement of brakes in general.

R. E. Fielder said that in motorbus operation the braking area is an important element and that four-wheel brakes are necessary. R. W. A. Brewer was of the opinion that the difficulty is to get a braking surface that can be relied on, the ordinary type of braking fabric varying greatly in its effectiveness from time to time.

C. J. Everett felt that brake designers pay too little attention to kinematics, and that as a consequence in some constructions the brakes become set when driving uphill and released when descending a grade. R. M. Werner referred to his experience in encountering this same condition. Harold Nutt advocated strongly the use of four-wheel brakes for reducing the number of fatal accidents in city driving. Charles M. Manly said that the most important point to consider in connection with the desirability of installing four-wheel brakes is how the energy of the moving car can be absorbed most effectively on slippery streets; and that the determination of this matter is largely the criterion as to the necessity for four-wheel brakes. The rear-wheel brakes are adequate if they will meet the conditions outlined. President Erskine, of the Studebaker Corporation, sent a communication calling attention to the statement of disadvantages of four-wheel brakes as set forth in the advertising of that company.

In replying to discussion and questions, Mr. Crane said that there is no doubt of the necessity of brakes being easily adjustable and that it is possible to accomplish this, as well as good accessibility, in a simple design; that in braking with the engine backfiring in the muffler can be avoided if the carbureter adjustment is correct; and that the selection of the best material for band brakes is determined largely by how good a brake is desired and how much room there is to install it. Furthermore, that the fabric with which he had had most experience was straight asbestos with woven wire, and that in his opinion molded lining, while suitable for brake-shoes, is not suitable for bands. He advised oiling the transmission brake if it is properly protected. In this case, however, there must be a greater leverage to offset the condition. In braking with the engine, the leading factors are engine friction and the pumping loss, this accounting for the greater effect of engine braking with the throttle closed. It is difficult to secure a high enough coefficient of friction with metal-to-metal brakes. This arrangement may be used in a transmission brake if the temperature of the brake does not become too high.

At the Nov. 15 meeting of the Metropolitan Section, Prof. E. P. Warner will present a paper on Commercial Air Travel.

UNCONVENTIONAL ENGINE VALVES

Three Experimental Types Described at Meeting of the Detroit Section

ABOUT 150 members attended the first fall meeting of the Detroit Section on Oct. 4 at the General Motors Building, Detroit. Papers describing new departures in valve design were presented by O. D. Heavenrich, Guy Disc Valve Motor Corporation, Ypsilanti, Mich., and Eugene Bournonville, Bournonville Rotary Valve Motor Co., Jersey City, N. J. Mr. Heavenrich described a Rotary Disc Valve Engine, built by his company, and Mr. Bournonville discussed Rotary Valves for Internal-Combustion Engines. R. Abell, general

THE 1923 PRODUCTION MEETING

Will Be Found Described in This Issue of THE JOURNAL on p. 429

[illegible] of the Single Valve Engine Co., Mattapan, Mass., who recently read a paper on Single-Valve Internal-Combustion Engine Design and Operation before the New England Section, [illegible] illustrating some of the important features of the paper.

A Rotary Disc Valve Engine

[illegible]

Mr. Bournonville, in reviewing the early efforts to perfect a rotary valve, said that about 2500 patents had been taken out but that for the most part they were freakish in design, had no reliable means of automatic and fool-proof lubrication, and that no successful attempt was made to take care of the expansion and the contraction of the parts coming into contact with the ignited gases.

He said that in investigating the subject he had devoted his attention first to expansion and contraction. As the conduction of heat through metals is very rapid a valve was designed having very heavy walls so that local heating was almost impossible, and uniform expansion of the valve was obtained. To keep the valve cool relative to its casing the carbureted mixture was made to pass from the carbureter through bored holes in the center of the valve. The gas, leaving both ends of the valve, enters a passage extending the full length of the valve head, and this passage, being open on one side, exposes one-sixth of the entire surface of the valve to the wet mixture, thus serving to cool as well as to lubricate it. At first, lubrication was effected by mixing 1 pint of light lubricating oil with 5 gal. of gasoline. While experimenting with a Fiat engine he found that the use of a rotary valve increased the speed from 55 to 65 m.p.h. and the miles per gallon of gasoline from 9 to 12½. This car has covered over 70,000 miles since that time without the valve's requiring any attention whatever.

In his first experiments with a rotary valve on a Willys [illegible] engine, though the horse-power at 1000 r. p. m. was increased from 28 to 32, when the speed was increased to 2000 r. p. m. the valve seized and the engine was ruined.

After building 25 engines during the last 12 years, a self adjusting valve has finally been perfected that takes care of expansion and contraction and the wear of the valve in its casing.

The main points that must be provided for to operate a practical rotary valve engine properly are as follows:

(1) Uniform contraction and expansion of the valve and its casing

[illegible]

(2) An automatic and dependable oiling system

(3) Constant contact between the valve and its casing

(4) Automatic adjustment for controlling the results of expansion and contraction of both the valve and its casing

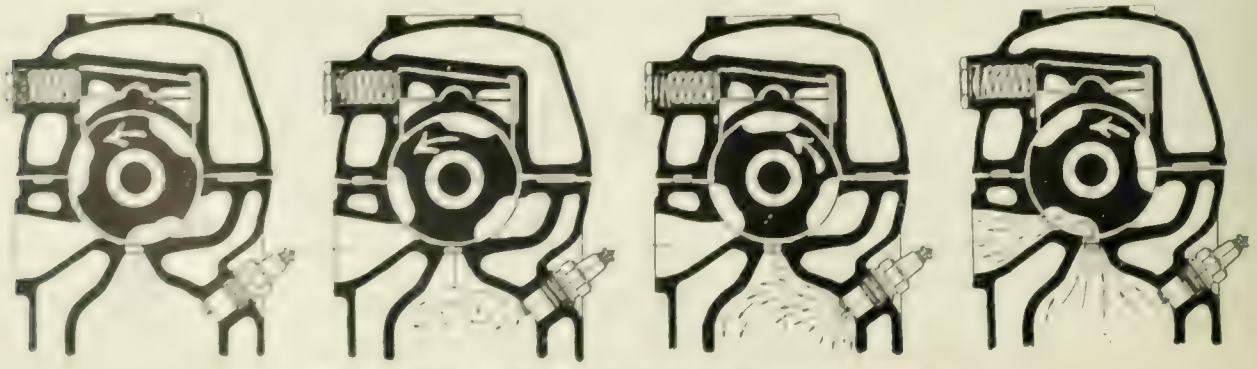
(5) Means of taking care of the wear of the valve and its casing automatically throughout the life of the engine

(6) There must be absolutely no clearance between the valve and its casing, while at the same time friction must be eliminated to such an extent that no undue loss of power will occur

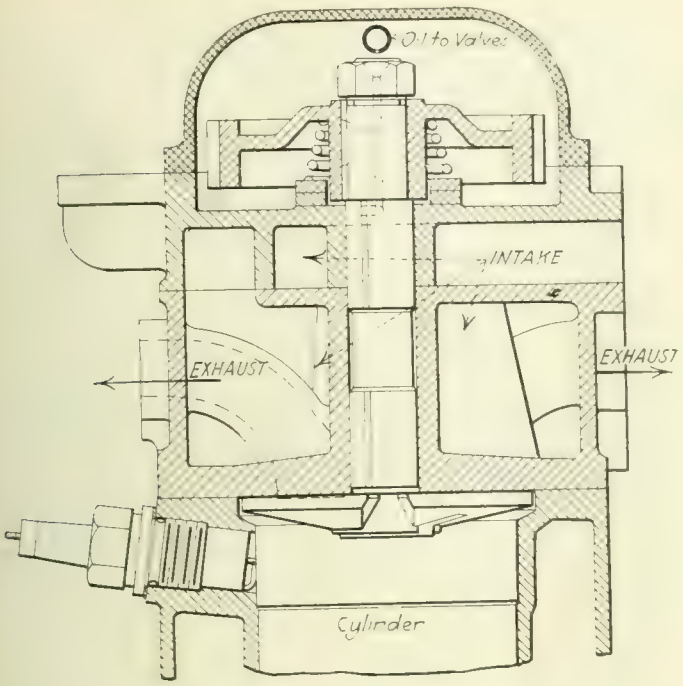
Rotary-Disc Valve Engine

Calling attention to the great amount of experimental work that has been done in recent years toward developing a valve mechanism that will do the work of the poppet valve without making so much noise, Mr. Heavenrich said that probably the best known non-poppet valve engine was that using the double reciprocating sleeve, but that this type, while giving excellent service, necessitated a considerable amount of accurate machine work and that proper lubrication was a problem. Another engine, less well known, has a single sleeve with a combined reciprocating and revolving motion. Other types of piston-valve and rotary-sleeve engines, and those having revolving cylinders, revolving pistons, rotary plug valves, rotary disc valves, and the like, usually are either too complicated, or too expensive to be practical. The engine most closely resembling his own was the Reynolds rotary valve engine, built a few years ago in Detroit.

The engine under discussion is not of the poppet valve, sleeve valve, rotary plug-valve type, nor any combination of them. The valve was said to be a cast-iron disc, machined flat on one side and having four equally spaced radial slots or ports. It is mounted on the lower end of a stem that comes through the head and turns the valve continuously in one direction against the bottom face of the cylinder-head, which contains the intake and the exhaust-ports. One valve is used in each cylinder, alternately opening the four exhaust and the four intake-ports in the cylinder-head and operating at one-eighth the speed of the crankshaft. A feature of the valve is a flexible connection to the valve-stem that allows the valve enough wabble to take care of any slight misalignment in machining, or in clearance around the valve-stem, while still maintaining a seal against the pressure in the cylinder. The valve is driven by a square key, fixed in the end of the stem and fitting into a keyway milled across the boss on the under side of the valve. The valve-stem is turned by a plain cast-iron spur-gear on the upper end of the stem above the head, the gear train being protected by an aluminum cover. In four- and six-cylinder engines, the drive is taken from the front end by a horizontal shaft that runs as far back as the center main bearing. At this point it operates, by worm or spiral gears, a vertical shaft running at one-eighth of the crankshaft speed. The whole valve-mechanism is most satisfactorily quiet. There are no reciprocating parts, no intermittent motions, nothing to clatter.



[illegible] Four Cycle Positions



Guy Rotary Disc Valve Construction

Each part has a continuous rotary motion and is always in metal-to-metal contact with its neighbor, so that even with poorly machined or badly worn parts the same quietness of operation prevails. No figures as to the amount of power required to operate the valve have been obtained, but the driving sprocket is held in place at the front of the driving shaft by a ¼-in. Woodruff key, unassisted by a clamping nut, and has given no trouble. The whole valve-mechanism, when set up ready for running, can easily be turned by hand, the only load being the friction load caused by the springs holding the valves in their seats.

Advantages Claimed for Disc Valve

Among the advantages claimed for the disc valve over both the poppet valve and the sleeve valve are the following:

(1) Continuous metal-to-metal contact and absence of reciprocating parts make an essentially quiet drive

(2) It compares exceptionally well in the matter of holding compression, its flat surface being maintained in contact with a flat seat by the pressure of a light spring at the top of the stem and by the pressure in the cylinder

(3) There is no problem of expansion and contraction. Any expansion is taken up in the spring and the efficiency of the valve is the same whether the engine is hot or cold

(4) Disc valves are not ground or lapped in. The filler of carbon and oil that forms after a few hours' running makes an ideal seat. Trouble due to the warping of the valves that was encountered during the early experimental stages was ended when the ribs that had been used for stiffening were cut off. Heat-treated alloy-steel valves do not work as satisfactorily as cast iron

(5) The under side of the valve forms part of the combustion chamber and carbon collects on it, as on any other part of the chamber, but is immediately rubbed off the working surface

(6) Notwithstanding that they are subjected to intense heat, the edges of the valve ports remain sharp, for the valve is at all times in contact with its water-cooled seat

(7) Lubrication of the valve is taken care of by gravity

(8) As four columns of gas rush in through four ports and gradually change their direction as the ports close, a beneficial condition of turbulence is set up; the four exhaust-ports situated in the head of the combustion-chamber also give excellent scavenging

(9) Any desired timing of the valves can be obtained; as the valves set directly over the centers of the cylinders the valve capacity is limited only by the distance between the centers

(10) The cost of construction in quantity production should compare favorably with that of any other type. All parts are easily machined, no special materials are required and the small number of parts cuts down assembling costs

(11) As a simple horizontal shaft is used to carry the drive, instead of a camshaft, it can be used to take care of some of the accessories

Combined Poppet and Distributor Valve Type

R. Abell

In opening the discussion, Mr. Abell showed some lantern slides of the engine described in his paper. The engines developed by Mr. Heavenrich and Mr. Bournonville, he said, were without poppet valves; that which he described had one poppet valve for each cylinder and a rotary distributor in series with it. The distributor is so called because it is subjected to neither compression nor explosion pressures, but serves only as a deflector in the manifolds, and switches from the exhaust to the intake-port when the piston is going over top center at the end of the exhaust stroke. In this position the valve is wide open and the cam, which has a long dwell, is exactly midway in the travel in that dwell. In two-valve engines the difficulty in closing the valves positively is that the exhaust-valve is under minus pressure, which tends to pull the valve from its seat and destroy the mixture, especially when operating at low throttle. This condition does not obtain with the single-valve engine because the valve is wide open and because of the rotary distributor. The outstanding feature of the engine is the combustion and the thermal gain in the temperatures at which the engine operates, as well as its ability to operate and hold its port at a high range of speeds. Another advantage is that the hemispherical combustion-chamber presents the minimum of heating surface to the flame and at the same time has the maximum of cooling surface in contact with the water because the chamber is interrupted with only one port. The valve serving both exhaust and intake is kept at moderate heat, the maximum temperature at the edge of the valve being about 500 deg. fahr. under any condition of speed alone. A new valve run in an engine at low speed showed blue in color when removed. No special steel is required for the valve; cast iron may be used if preferred. The part above the valve is really an extension of the combustion-chamber at one point in the cycle, so that the total amount of dilution with a 7.5 to 1 compression-ratio is just equal to that of a normal engine with a 4.5 to 1 compression-ratio; the flame temperatures are equal although in the first case the compression-ratio is much higher. This is accounted for by Ricardo's statement that a variation of 1 per cent in the weight of the exhaust gas, plus or minus, would raise or lower the flame temperature 45 deg. fahr.

Discussion Brings Out Interesting Data

Replying to a query as to the water-cooling of the head of the cylinder, Mr. Bournonville stated that there is approximately 3/32 in. of metal around the ports of his engine and that the valve turns up to the stem is filled with cooling-water and that no trouble on account of uneven wear of the valve caused by the cooling of the stem had been experienced, as had been reported in other engines.

Regarding compensation for wear, if one cylinder should wear more than another, Mr. Bournonville said that wear would not take place and affect one cylinder alone; that as the valve is spherical and the casting also cylindrical, if wear were to occur in one place so that the valve did not make contact, contact would take place at some other point and the low spot would fill up with carbon until the wear became equal again. Rotary valves should not be ground for adjustment, their nature not to surface is like that of a [illegible]. The machining of the tapered seat is perfectly flat. A difference of expansion, if the cylinder block and head were separate, and a possibility of leakage, Mr. Bournonville said, were obviated by the fact that the cylinder, the head and the valves were all water-cooled; that no leakage of any kind had occurred whether running on six, four or two cylinders.

When questioned as to the actual compression-pressures that were obtained at from 400 to 1000 r. p. m. at a compression-ratio of 8 to 1, Mr. Axtell said that at 200 r. p. m. the compression pressure at a compression-ratio of 10 to 1 averaged about 180 to 185 lb. per sq. in., at 8 to 1, about 150, and at 7 to 1, about 130. Concerning fuel economy at part loads, he said that on a run of 130 miles, with a car weighing 3400 lb., a gear-ratio of 4½ to 1, and the speed sometimes exceeding 70 m. p. h., 20.6 miles were covered per gallon; for ordinary touring the average would be from 20 to 25 miles. The maximum explosion-pressure he had ever obtained he had estimated to be 600 lb. per sq. in.

PRECISION BEARINGS BUFFALO TOPIC

Production of New Type Discussed and Demonstrated at Unusual Meeting

On Oct. 1 a meeting of unusual interest was added to the Buffalo Section schedule. Lees W. Chadwick, of the Chadwick-Le Roi Co., presented a paper on The Use of Precision Bearings on Engine Crankshafts. His talk was illustrated by slides and practical demonstrations in which he was assisted by Mark Harris, of the Oakland Motor Car Co.

Mr. Chadwick began with a statement of the modern manufacturing equation:

STANDARDIZED ACCURACY — INTERCHANGEABILITY = UNIFORMITY — ECONOMY.

The interchangeable bearing is produced by a method, later described in full, which makes its adoption commercially possible by reducing the cost of production.

According to Mr. Chadwick, the following qualities are necessary for a perfect bearing:

(1) Be perfectly seated in its support; in this case, the [illegible] connecting rod

(2) Have an unbroken surface that gives the oil-film a [illegible] support

(3) Have an installation with the correct oil clearance [illegible] of the time

(4) Be constructed of materials that have sufficient strength to withstand the effects of the load for the life of the engine, have satisfactory anti-friction and [illegible] qualities and have a melting point high enough to resist destruction by heat, but one enough to act as a safety valve in case of lubrication failure

(5) Its fabrication and installation must be commercially possible

The first three factors, constituting installation or fitting, are, in Mr. Chadwick's opinion, the most important. His experience with high-speed machinery working under unusually severe conditions over a long period of time and the wide variation in the length of life of bearings made of the same materials and running under the same conditions convinced him that fully 60 per cent of bearing failures, excepting lubrication failures, are caused by faulty installation, resulting in insufficient bearing area and incorrect clearances.

As to the fourth factor, bronze is a material that at once suggests itself, as it possesses more of the required qualities than any other metal and permits the easy bonding to it of a metal having the requirements that the bronze itself does not possess, anti-friction and low melting point.

Babbitt the Ideal Lining

Babbitt has proved to be the most suitable metal for the lining, as it possesses the required melting point and anti-friction qualities. Its defects are that it does not have sufficient strength to resist indefinite pounding; it is expensive and will not form a satisfactory union with the bronze without the interposing of another metal between them. Its inability to withstand pounding is offset, first, by using as small an amount as is commercially possible, say from 1/64 to 1/32 in. of lining, which also helps heat-radiation and makes the bearing cheaper, and second, by proper casting methods that densify the structure, thus utilizing its maximum strength.

Mr. Chadwick reported that he had best results from a babbitt formula of 85 per cent tin, 7½ per cent copper and 7½ per cent antimony. As with bronze, the proper handling is more important than exact specifications, providing that impurities are kept out.

The metal for bonding the babbitt to the bronze must, for manufacturing reasons, have a lower melting point than either of the others. Pure tin and various lead-tin alloys are generally used for this, lead-tin being the most popular with bearing manufacturers because it is easier to use, but as the bonding metal determines the ability of the bearing to resist failure due to overheating, it is not so desirable from the engine-builders' viewpoint as pure tin. Pure tin has a melting point of 450 deg. fahr., while the average lead-tin alloy has a melting point of about 360 deg. fahr.

Precision Process Step by Step

The process of producing these precision bearings in itself answers for the fifth factor. As outlined by Mr. Chadwick, it is as follows:

Operation 1—Cast bronze bushings
Operation 2—Bore inside diameter
Operation 3—Tin bronze shell
Operation 4—Turn outside diameter
Operation 5—Babbitt
Operation 6—Bore babbitt
Operation 7—Broach
Operation 8—Grind
Operation 9—Split
Operation 10—Swedge
Operation 11—Finish center line faces
Operations 12 and 13—Drill and cut oil grooves
Operation 14—Burr inside and outside diameters

Every bearing is carefully inspected and all fins and burrs are removed. The result of the finished process is a product that meets all the requirements of a good bearing and then makes it practically impossible for the assembler to get a fit that is not within the prescribed limits, providing, of course, that its related parts, the crank and the crankcase, are also within the required limits. Every bearing so made has maximum contact and correct oil clearance independent of the skill of the workman.

The standard time for assembly of bearings and crankshaft is 3.6 min. In service, it is possible to replace these bearings in a small fraction of the time required to replace and fit the other types, with the assurance, moreover, that the job turned out will be first-class, independent of the skill of the workman. One company has found it possible to cut down the standard time on this operation from 45 to 4 hr.

In the discussion that followed, Mr. Chadwick was questioned on the possibilities of babbitting aluminum rods. He answered that it is somewhat more difficult to babbitt aluminum rods, but that it can be done successfully, although aluminum oxidizes more quickly than steel. The tin can, however, be rubbed into the aluminum with a wire brush.

Another point raised was the disadvantages of thick babbitt, aside from its cost. Mr. Chadwick explained that, in the first place, babbitt is only used to act as a safety valve in case of lubrication failure. It is put in so that, if the engine becomes overheated, instead of making a sudden seizure, it will melt and flow. It will pound out because it is soft, and naturally 1/16 in. will pound out twice as much as 1/32 in. Babbitt 1/64 in. thick can be put on satisfactorily. If put on 0.005 in. thick with a paint brush, it would be just as satisfactory.

Asked at what temperature to pour or pump the babbitt, Mr. Chadwick replied that it depended largely on the mixture. The babbitt should be kept just above the segregation point and not as high as the point where oxidization takes place, according to his experience. One cannot, however, go below the point where the metals will not fuse with one another. From 800 to 825 deg. fahr. is a satisfactory temperature, varied according to the size of the bearing and other conditions.

BALLOON TIRES ARE HERE TO STAY

J. E. Hale of Firestone Discusses Their Performance at Indiana Section Meeting

A review of the reactions of the considerable proportion of the public that has become accustomed to riding on low-pressure air, and of the car builders that have been experimenting with sample sets of balloon tires, led J. E. Hale, of the Firestone Tire & Rubber Co., to some interesting conclusions on the future of the low-pressure tire at the meeting of the Indiana Section on Oct. 11.

J. E. Hale

The demand for low-pressure tires has actually existed for a long time. The tire companies' adjustment records show underinflation to be one of the most flagrant forms of tire abuse. It is a common practice of car-owners to run on low inflation deliberately for the comfort and protection that they can secure. As the indications are that they intend to take matters into their own hands and ride on low pressure with their present equipment, the problem is to produce the true low-pressure tire that the manufacturer can stand back of.

The individual's reaction to the question of the low-pressure tire is somewhat as follows: How does it affect the steering? Does it cut down the fuel consumption? How much do they cost? What air pressure is used? Well, can I buy a set for my car?

When, true to the responsibilities of their positions, car designers proceeded to search for objections, they found that the balloon tires, having some different characteristics from high-pressure pneumatics, could not be substituted without due consideration for these differences. Their attitude toward them ranges all the way from actual adoption by certain companies to direct opposition, with all kinds of opinions between.

Objections Answered

So far as economic reasons unfavorable to air-cushion tires are concerned, the monetary appropriations involved are not excessive, since they are confined to fender changes, details of brake design and axle design to provide additional offset.

As to engineering obstacles, Mr. Hale has not heard of anything insurmountable. There have been cases where the fenders were not wide enough with the new equipment and mud would be spattered, but this is not insurmountable. A few designers have encountered front-wheel shimmy and for that reason have disapproved of this form of equipment. This trouble almost never occurs at speeds below 60 m.p.h. A few cases of front-wheel shimmy on change-over jobs have come to Mr. Hale's attention, but in all these cases the shop mechanics have been able to make some adjustment in the steering mechanism which corrected it. Mr. Hale has found that on his own car he can bring about front-wheel shimmy by slacking off a three-quarter turn on a certain nut in the steering linkage.

The effort required for steering receives very prompt consideration. A soft tire steers a little harder, but steering-gear changes have already been made which give satisfactory results in this case.

Another objection is the belief that the ability to pick-up and to accelerate is slightly affected by low-pressure tires, but as far as Mr. Hale has been able to determine, low-pressure tires affect the engine performance only slightly.

As far as fuel consumption is concerned, there is plenty of evidence that this is not affected adversely. Mr. Hale has himself just completed a 1200-mile vacation trip in a 4-year-old roadster equipped with balloon tires, averaging 17 miles per gal. for the entire trip.

Schedule of Sections Meetings

NOVEMBER

1—Detroit Section—Development of the Commercial Airplane—W. B. Stout.
2—Washington Section—Repainting and Refinishing Automobile Bodies—C. O. Thomae
6—Dayton Section—Better Automobile Headlighting and the Importance of Accurate Equipment and Proper Adjustment—R. N. Falge
New England Section—Brakes—W. S. James
7—Minneapolis Section—Analysis of Various Four-Wheel Brake Designs—C. W. Jacobs
8—Indiana Section—Records of Spring Movement in the Action of Cars—T. J. Litle, Jr.
9—Mid-West Section—The Relation of the Automotive Manufacturer to Motor Transport—David Beecroft
15—Metropolitan Section—Commercial Air Travel—E. P. Warner
Detroit Section—Gears—Is It Necessary to Grind?—Round Table Discussion
19—Cleveland Section—Engineering Aspect of the Used Car—David Beecroft

"Cannonball" Baker Proves Safety of New Tire

[illegible] of serious accident have been made if one of these [illegible] tires should burst on a vehicle at high speed [illegible] a front-wheel tire. So far there has been no trouble from this source. "Cannonball" Baker had a [illegible] tire go flat while running at 55 m.p.h. and reported that there was no particular difference in the performance of the car between the 7.50 balloon tire and similar occurrences that he had previously had with the regular 33 x 5 high-pressure tires. The only reaction was a slight tendency for the car to draw to the flat side. He also had a tire go flat on a rear wheel when running at 75 m.p.h., but he continued at high speed for 15 miles on the flat tire.

Personally, Mr. Hale does not believe that it is possible to adapt the present line of tires and rims to produce a true balloon tire by oversizing and splitting the difference in the number of tires used.

In the engineering of the development department with which Mr. Hale is connected, four sizes of tire are necessary to satisfy properly the various cars and at the same time follow the pressure recommendations of from 20 to 35 lb. In a general way, the choice of tire sizes to be applied to the various cars is shown in the accompanying table.

BALLOON AND PNEUMATIC TIRE SIZES FOR VARIOUS WHEELBASES

Balloon Tire, Actual Section Diameter, In.	High-Pressure Pneumatic Equivalent Size, In.	Maximum Load per Wheel, Lb.	Wheelbase Range of Cars for Each Size of Tire, In.
4.40	3½	750	100 to 103
5.00	4	1,000	108 to 115
6.00	4½	1,300	118 to 126
7.00	5	1,700	130 to 140

Shock Absorbers an Essential Addition

In his Summer Meeting paper, Mr. Hale mentioned the necessity of shock absorbers or spring rebound checks and predicted a disappointment with balloon tires without these accessories. At the Indiana Section meeting he emphasized the point even more strongly. The low-pressure tire will take care of the pavement irregularities in splendid shape, but depressions and humps from the general road level seem to produce an excessive rebound and the only apparent remedy is to have rebound checks, but great discrimination must be used in choosing the proper make of check. It is a very complex situation in which the spring characteristics play a very important part. It is an advantage to keep the spring leaves well-oiled.

Too the manufacturers feel that the automobile industry should consider this tire equipment in its hands, and it is for the industry to decide what is to be done with it.

Mr. Hale summarized the situation as he sees it as a result of close association with the public and manufacturers as follows:

(1) Unquestionably the public will ride on low-pressure air.

(2) The tire companies must meet the situation by designing and marketing tires that can be used with low-pressure air.

(3) The market demand for balloon tires unquestionably will be so great that a large number of existing cars will be changed over.

(4) The public will not care for balloon tire equipment because it looks better, rides better, brakes safely, and saves the car.

(5) Once the car builders have learned what balloon tires will do for a car, they will be able to design lighter and simpler cars.

(6) The January Show will see many cars equipped with balloon tires on the floor.

Moving pictures were shown to demonstrate Mr. Hale's points and suggestions followed. Asked about the life of tire fabrics and as affected by road fatigue, Mr. Hale replied that it was his impression that the quality of a good quality cotton tire to flex repeatedly is so great that it will continue to function in that way as long as the rubber is in good condition. Flexing, however, weakens the cotton.

No Tread Cuts in Balloon Tires

Another question asked how the tire would wear in deep ruts and rough spots. Mr. Hale said that it would not show any tread cuts at all; being soft and not having such intense pressure back of it, it does not fight the road but simply folds itself over. The same thing is true on the side-walls. One can run up against curbs as frequently as may be desired without hurting the tire. One of the big troubles with most tires is the question of tread separation, but Mr. Hale's company has not had a single case of tread separation in balloon tires.

Charles S. Crawford expressed the opinion that, regardless of what the engineer thinks about balloon tires, his opinion will be over-ridden by the general public. It is as well, therefore, to pave the way for the use of them and to do everything possible to benefit the installation. According to Mr. Crawford, the matter of steering resolves itself into making the steering ratio in proportion to the kind of tire used, the load imposed on it and the kind of steering the person wants.

Howard Marmon reported that his experience with balloon tires has been very satisfactory in the riding qualities, but that at present he has not been able to get a satisfactory ratio on the steering mechanism. For ordinary driving, the car steers well but shows a tendency to lean on one side or another.

Charles R. Short emphasized the point that the benefit possible in the use of balloon tires cannot be realized by taking the old chassis with standard springs and standard steering-gear and applying balloon tires. Both the steering-gear and the springs must be modified to benefit from the lower rate of vibration.

The next meeting of the Indiana Section will be addressed by T. J. Litle, Jr., on Records of Spring Movement in the Action of Cars. The meeting will be held on Nov. 8 in the Severin Hotel, Indianapolis, beginning promptly at 8 o'clock, after an informal dinner at 6:30 p. m.

THE USED CAR AS AN ENGINEER SEES IT

The Cleveland Section will hear David Beecroft, of the Class Journal Co., on the Engineering Aspect of the Used Car at the Nov. 19 meeting at the Cleveland Hotel. Dinner at 6:30 p. m. will be followed by a half-hour's entertainment before the meeting, which will begin promptly at 7:30 p. m.

JOINT MEETING IN DAYTON FOR FALGE

R. N. Falge, of the National Lamp Works, General Electric Co., will speak on Nov. 6 as a specialist on headlighting before a joint meeting of the Dayton Section of the Society and the Dayton Engineers Club. His topic will be Better Automobile Headlighting and the Importance of Accurate Equipment and Proper Adjustment. The meeting, which will be held at the Dayton Engineers Club, will begin promptly at 8 o'clock.

NEW SECTION FORMING IN MILWAUKEE

Stoelting Talks on City Planning and Traffic Control at First Meeting

Members in Milwaukee are holding regular meetings as one of the preliminaries required for the formation of a new Section. At the first of these meetings, on Oct. 24, R. E. Stoelting, Milwaukee Commissioner of Public Works, discussed the transportation problem from the viewpoint of the city, speaking on The Relationship of Automotive Vehicles to City Planning, Traffic Control and Pavements.

Mr. Stoelting emphasized the necessity for careful planning in the future, to avoid jammed traffic streets inadequately

laid out for their loads. Rapidity, safety and parking facilities are essential factors of the problem to solve which properly it will be necessary to spend as much as the total spent for automobiles to date.

As solutions of the parking bugbear, the speaker suggested municipal garages of immense capacity and small fee and parking facilities for customers' cars on store roofs. He also outlined the need for an arterial highway system with automatic controls at the intersection of highways, more of which are being developed in Milwaukee than anywhere else.

In the future Mr. Stoelting believes that city traffic will be handled by buses, allowing the use of the full street width. In closing, he appealed to engineers for assistance in solving civic problems.

Later meetings will discuss transportation from the point of view of the highway engineer and from various angles in the automotive field. The group meets in the Library Hall on the third floor of the Milwaukee Public Library, Grand Avenue between Eighth and Ninth Streets.

KETTERING SPEAKS AT MID-WEST SECTION

Says Engineer Must Cooperate with Other Departments and Widen Viewpoint

That one of the grave problems which the engineering fraternity has ahead of it is to settle down and recognize that engineering as an accomplishment is only an accomplishment in so far as it produces a favorable change of figures in the balance sheet and that it is time for the engineers to begin to work out an engineering audit sheet on the work they are doing were the first points stressed by Charles F. Kettering, of the General Motors Research Corporation, in his address to the Mid-West Section at its Oct. 12 meeting.

C. F. KETTERING

In developing his argument, Mr. Kettering insisted that one of the biggest problems in front of the engineer today is to acquaint himself more with the economic and business phases of the industry in which he is involved. It is not sufficient for him to lock himself up in his designing department and design something, because he cannot design something apart from his users. He had better spend 50 per cent of his time out in the field with his users and the other 50 per cent in the engineering department designing something, designing improvements, than to spend all of his time in the engineering department, because he must meet the requirement that all engineering is to proportion material in such a way as to render the greatest possible service to his users, no matter what the thing is.

Engineering Closely Related to Cost Department

The engineering department should be adjacent to the cost department. If one has to meet competition and make a 10 per cent reduction in cost, he has some chance of making it if he analyzes the costs of the individual pieces and begins to take the 10 per cent out of each piece. The engineer must take more into consideration than the simple functioning of the article he is designing; he must become the economic control factor. The engineer has never been very much interested in the question of overhead, but he has just as much to do with overhead as anybody else, since it is an engineering problem.

There has been a perfect mania for special machinery during recent years. Mr. Kettering cited figures to show the fallacy of using expensive special machine-tools to perform simple machining operations and said that the question of the kind of machinery needed and the way parts are designed is a very important responsibility. The designer is really responsible, to a certain extent, for the capital investment and for the floor space.

In every big organization there is always a scrap between the engineering department and the production department. There is one best way of settling that, and that is to have the better educated fellow give in. Swallow our pride and get the result regardless of whether we get credit for it or not. Our job as research engineers is not to look upon the automobile as a finished commercial product today but to look at it to try and find out what is wrong with it. Research is simply a state of mind and the way we get that state of mind is to be dissatisfied with something we have got or something we are doing. To put it in another way, research is the correction of a fault.

Expanding Viewpoint Essential to Progress

The average engineer never realizes that he is getting older every year. He graduated from school when he was 22 years old and could see things. He gets older, and along about 35 or 40, he passes the center of population; in other words, there are just as many on this side of him as there are on that side of him. As he gets a little older, he sees things in terms of what he used to be and he is in a foreign country, so far as his notions are concerned. If he does not get back and get the new point of view, he is lost. Whenever one feels that he is getting his job licked into good shape, it is an indication that he has had the shutters closed on his windows and must get out and get another viewpoint. Mr. Kettering believes that an engineer ought never look for the rock bottom end of anything. There may be a limit to the thing as he sees it today, but with new things coming in all the way along the line, the ultimate cannot be prophesied.

Mr. Kettering illustrated how radical changes in viewpoint have been responsible for revolutionary changes in the painting of motor cars. He cited another case in which persistent study, unhampered by satisfaction with initial progress, resulted in lengthening the life of fan-belts 70 times that expected before research was undertaken. He also presented many interesting comments on the progress of scientific research in other fields such as chemistry, physics and medicine and pointed out the fundamental relationships between them.

American industry today with the research laboratories that are being established, with its more open-minded attitude and with a closer association of the engineers to the business management gives every opportunity in the world for a marvelous advancement.

A big motor transport meeting is planned as the November number on the Mid-West Section's program. Fleet owners and service-men are especially invited to hear David Beecroft, of the Class Journal Co., on The Relation of the Automotive Manufacturer to Motor Transport at the meeting on Nov. 9 in the Western Society of Engineers' rooms, Monadnock Block, Chicago. The meeting will begin at 8 p. m. after an informal supper at 6:30.

MANUFACTURE AND USES OF DURALUMIN

Alloy Developed for Aircraft Purposes Finds Many Automotive Applications

Duralumin and its applications was the subject discussed at the meeting of the New England Section of the Society held at the Highland Hotel, Springfield, Mass., on Oct. 23. Following the customary dinner, R. E. Northway, chairman of the Section, introduced R. W. Daniels, sales engineer of the Baush Machine Tool Co., who presented an exceedingly instructive paper on the recent developments in the use of this aluminum alloy that was brought to its present state during the war and has played such an important part in the construction of both airships and airplanes.

In the afternoon preceding the meeting a visit was made

making it in England and granting a license for production in France. Soon after the close of the war its manufacture in this country was undertaken and it is now produced in all forms and of a quality equal to the best foreign product.

Duralumin is an aluminum alloy that, when wrought and heat-treated, combines to a remarkable degree the lightness of aluminum with the strength and toughness of the ferrous metals. When subjected to ultimate stress, it is at its best the equal of most open-hearth steel that is stressed to the same percentage of its tensile strength. It is recognized as occupying the same relative position to ordinary wrought aluminum that heat-treated alloy-steel does to ordinary mild steel. The principal and unusual feature of the alloy is that after it has been hot or hot-and-cold worked it may be further strengthened and toughened from 40 to 50 per cent by a heat-treatment that is analogous to the heat-treating of alloy-steels and consists of quenching from temperatures below the melting point followed by an aging process in which the alloy is maintained at a minimum temperature of 70 deg. fahr. Its maximum qualities are not reached until a period of at least 48 hr. has elapsed. Higher temperatures shorten the aging period but do not commercially affect the results.

In composition, the principal constituents of duralumin are aluminum, plus its usual impurities of silicon and iron; copper, 3 to 5 per cent; magnesium, 0.20 to 0.75 per cent; and manganese, 0.4 to 1.0 per cent. Small quantities of other metals such as chromium are sometimes added for specific purposes. The melting point is approximately 1200 deg. fahr., the annealing temperature preferably 680 to 700 deg. fahr., and the heat-treatment range 910 to 970 deg. fahr.; the coefficient of expansion is 0.00012 in. per degree of temperature. When heat-treated its strength is comparable with mild steel, section for section, while its specific gravity is 2.81 compared with 7.80 for steel.

When used in the proper condition, duralumin lends itself admirably to the ordinary methods of manufacture; it may be cast, hot and cold-rolled, extruded, forged under the press or the hammer, or on the bolt machine; it may be drawn, spun and stamped in the crank or toggle press similarly to soft steel; it may be machined readily and when so used cuts with a clean chip, without tearing or dragging, at a considerable saving of time over that of steel and most other metals. It is corrosion-resistant, highly resistant to atmospheric influences and to the action of both fresh and salt water; is only slightly affected by the chemicals that attack most metals and does not tarnish in the presence of sulphuretted hydrogen. In appearance it closely resembles silver, takes a polish equal to nickel plating, remains bright without cleaning longer than any plated or silvered article and is not stained by handling.

Tests of the ultimate tensile strength of the heat-treated material vary with the dimensions of the test piece, showing a minimum of 55,000 lb. per sq. in. for bars less than 1 in. in diameter, or width across the flats, and a minimum of 45,000 lb. per sq. in. for bars over 2 in. in diameter, or in width across the flats. The corresponding yield-points are 25,000 and 23,000 lb. per sq. in. while the elongation is between 17 and 18 per cent in 2 in. Annealed material has a tensile strength of from 26,000 to 35,000 lb. per sq. in.

Four years of experience with duralumins at the plant have proved that failures are due to incorrect design, faulty workmanship or defective material and not to any change in the physical properties of the alloy. Defects caused by flaws, cracks, air bubbles and the like, are similar to those produced in steel.

The steps in the manufacture of duralumin are similar to those of steel and are (*a*) the manufacture of the alloy from its aluminum base; (*b*) casting the ingot; (*c*) hot rolling or forging the ingot into blooms, billets or plates; (*d*) hot or cold working into the final shape; (*e*) heat treating or annealing; and (*f*) further cold-working under certain conditions only.

During these various processes the physical properties are increased by distinct steps and the ultimate tensile strength may be increased from 6000 to 10,000 lb. per sq. in. by cold-working after heat-treating and aging. Annealed duralumin may be heat-treated and, conversely, heat-treated duralumin may be annealed. When annealed it can be drawn, spun, stamped and formed into a great variety of shapes, similarly to brass and mild steel; when heat-treated it combines a remarkable tensile-strength with the ability to be formed; when heat-treated and hard rolled it is used where no bending or forming is required.

Among the uses to which duralumin has been put are the structural parts and the wing and fuselage covering of airplanes, main-bearing bearing-caps, pump driving parts, and propeller flanges. The successful flights of the Shenandoah have been a notable achievement, and the fact that the winning airplanes in the recent speed contests at St. Louis were equipped with duralumin propellers is not generally known.

In automotive work its use is extended to such inertia parts as connecting-rods and to unsprung parts such as disc wheels and the hub caps of wire wheels. Its pleasing appearance when polished and its ability to withstand handling and exposure have increased the demand for it for such parts as hood catches, door handles, latches, and lamps.

Following the reading of the paper a lively discussion brought out many additional details concerning the various applications of the metal to automotive practice.

Mr. Daniels' replies to the questions asked may be summarized briefly as follows: Standard tests are necessary to determine crystallization from which, however, duralumin is remarkably free; that no trouble has been experienced with duralumin connecting-rods; that less time is consumed in machining when the work is stationary; babbitting imposes no difficulty, the melting point of tin being just under that at which duralumin begins to soften; no special preparation is necessary for tinning, as molten tin removes the oxide from forged duralumin as well as applies the tin; when babbitt is cast no reaming is necessary; duralumin can be die cast but is usually looked on as a metal that has to be wrought; successful die-casting depends largely on the manner of doing the casting; brake hangers are cast directly on the shaft; duralumin can be welded as well as aluminum; its conductivity is about 40 per cent of that of pure copper; in transmission spans the use of longer spans might prove economical; in rolling the strains imposed by heat-treatment are neutralized; duralumin may be used as a bearing metal with case-hardened steel and duralumin connecting-rods are used with steel crankpins; regarding the holding of heat before annealing, care must be taken that the heat goes entirely through the part; no advantage is to be gained in holding the temperature before quenching; if allowed to drop in temperature with that of the furnace the material will be more ductile; no color scheme has been worked out to indicate the kind of metal, but all shipments are marked; the Brinell test is the easiest method of determining the kind of metal; the fracture after the tensile test is fibrous, a round section showing a crystalline structure, a square section having the fracture on a slant; an unusual shape would indicate the presence of foreign matter; in general, the defects are similar to those to be found in steel; laminations are caused by air bubbles in pouring; it is not possible to tell with a microscope whether duralumin has been heat-treated.

Continuing further, he said that little trouble had been experienced on sea voyages but that salt water does affect the metal slightly, especially if it were to get between layers; although duralumin can be furnished in lengths suitable for the panels of automobile bodies, it is not much used for this purpose, as aluminum panels are good enough; no special

effort has been made to use duralumin as a bushing, but it would run cool and wear well with steel and alloys if sufficiently well lubricated; it is satisfactory as a bearing metal only when used with hard steel; a piston of cast duralumin would give the advantages to be obtained from light reciprocating parts, less vibration and better lubrication; the parts may be made smaller but if made the same size their life would be lengthened; pistons and rods frequently do not balance; either a light piston is used with a heavy rod or vice versa; it is of no advantage to balance a crankshaft and pay no attention to what is put on it; in price, duralumin cannot be compared with steel as the cost is from three to four times as great; it would compare very favorably with bronze; brass castings are today competing with bronze castings owing to the fact that with bronze the roughness is always at the fillets while with brass it usually is at the end.

The next meeting of the New England Section will be held at the Engineers' Club, Boston, on Nov. 6. Dinner will be served at 6:30 p. m. and the meeting will begin promptly at 8 o'clock. W. S. James, physicist of the Bureau of Standards, will discuss Automobile Brakes, with particular reference to those of the four-wheel type.

LOW-PRESSURE CORD TIRE PROBLEMS

J. F. Palmer Tells Buffalo Section That Cords Must Be Wound by Tangent Method

J. F. PALMER

Many of the engineering obstacles in the path of development of the low-pressure cord tire can be overcome by laying the cords on the carcass so that they are tangent to the base or rim circle of the tire. This is the opinion of J. F. Palmer, of the Dunlop Tire & Rubber Co., who addressed the Buffalo Section, Oct. 29, on the Problems of Low-Pressure Tires. Some of Mr. Palmer's comments are given in the following paragraphs.

Power efficiency and safety must not be sacrificed to mere ease in riding. Cords and rubber as used in pneumatic tires offer little resistance to distortion in the absence of air pressure, hence in reducing the air pressure below current practice it must follow that the stabilizing element is proportionately reduced in efficiency. Brief consideration of the conventional cord-tire structure exposes the engineering error of connecting the rim, which is the last rigid point in the power-transmitting line, with the road surface by tension members lying on a double curve. Until the tension in the cord structure is equal to the force acting upon it, it does not respond with useful work. This wasted effort causes nothing but frictional heat that, under extreme conditions, burns up a tube in a short time. This is exemplified in high-speed bus duty and constitutes one of the present problems in that service.

The problem to state it in few words, is to secure low air-pressure without doing it at the expense of cord tension, efficiency and safety. Tangent winding appears to offer a solution. In this scheme the path taken by the cords is tangent to the rim base, or rather to circles falling within the flange and extending from tread point to tread point, each course of these cords being slightly inclined to its predecessor. This construction builds up the beads by the over-lapping plies of cords and renders unnecessary any other provision for attaching the tire to the rim. It is apparent that under the air pressure this type of tire has no tendency to lift from the rim, but, on the contrary, will hug it. Each cord pulls progressively from tread point to tread point all the way around the tire, the rim base and the flanges serving only to give frictional contact for power transmission and any other duty imposed in use.

The tangent cord line coincides with the power line, viewed in side elevation and affords the longest possible length of cord from edge to edge of the casing on rims of any base diameter. For this reason, the air pressure can be proportionately less to maintain equal cord tension in the carcass members. Power losses in transmission are minimized because the long flat arc described by the cords creates a longitudinal base of the tire that is unequalled in any other construction.

Rim widths should be standardized. There is a proper width of rim for each size of tire and, for the best results, no other size should be used. This is of increasing importance as tires of larger sizes are used. Hence the term oversize as used today in relation to tires has, properly speaking, no relation to the duty or capacity of the tire but refers solely to the width of rim upon which it is used. The matter of cost has apparently been the determining factor in original rim equipment leaving to the purchaser the decision as to whether tires adequate for the duty required of them are supplied. If he decides that the engineers responsible for the job did not know their business, or knowing it failed in their duty, he buys oversize tires and puts them on the old rims. Tire manufacturers, willing to make anything in demand have created so-called oversize tires. Now we are confronted with double and even triple oversize tires, in an effort to graft the new idea of adequate cushioning upon the original inadequate rim.

MINNEAPOLIS TO STUDY BRAKE DESIGN

The Minneapolis Section met on Oct. 3 to plan for the development of the Section and arrange a program for the coming year. Appointments made by the Minneapolis Governing Board as follows went into effect at this meeting. A. F. Moyer, formerly vice-chairman, succeeds Victor Gauvreau as chairman, as Mr. Gauvreau resigned his office on leaving Minneapolis. C. T. Stevens and A. H. Bates will head the Membership and Program Committees.

The first meeting scheduled will be held on Nov. 7 at the Manufacturers Club, Builders Exchange, Minneapolis, beginning at 8 o'clock. C. W. Jacobs, service-manager of the Pence Automobile Co., will talk on the Analysis of Four-Wheel Brake Designs. He will discuss in detail the present systems of four-wheel brake layout, external contracting, internal expanding, "booster," equalized, non-equalized and differential. Types of brake-shoes and bands and methods of applying braking power will also be considered.

PAINT MEETING IN WASHINGTON

C. O. Thomae, technical expert with Valentine & Co., will talk to the Washington Section at its Nov. 2 meeting in the Cosmos Club on Repainting and Refinishing of Automobile Bodies. Mr. Thomae's long experience as a paint expert makes a valuable and interesting meeting certain.

THE AUTOMOTIVE PRODUCTION MEETING

Over 400 in Attendance at Second National Production Gathering in Cleveland

Although the attendance was not as large as that at the Detroit Production Meeting of the Society, the meeting in Cleveland on Oct. 25 and 26 lacked none of the interest or enthusiasm of the former occasion. Men were in attendance from all sections of the Country and most of the principal automobile companies were represented. The registration reached a total just in excess of 400 persons and each of the sessions was attended by upward of 200 production men. Over 250 members and their guests were seated at the Production Dinner on Friday evening where they enjoyed a

S. A. Heron

J. G. Younger

Chairman at Two of the Sessions

highly inspiring address by R. H. Grant, general manager of the Delco Light Co.

Most of the Production Meeting papers are printed in this issue of THE JOURNAL, but the following paragraphs report in abstract form the information that was brought out in the discussion following each of the presentations. Great interest was manifested in the paper on the wage-payment methods practised in the Chandler plant as will be noted by the number of points raised in the discussion. Questions and answers that followed the papers on grinding indicated a general tendency in the industry toward higher standards of dimensional precision and surface finish. No doubt this raising of manufacturing standards accounts for the reported increased durability and life of the modern motor car.

Many of the men in attendance at the meeting suggested the possibility of holding an exhibition of new machine tools in conjunction with future Production Meetings of the Society. It was thought that this plan would enable factory executives to inspect the latest developments in tools and methods at one time and place, thus conserving their time and increasing the service of the meeting to both the builder and the buyer of machine tools. A canvass will be made of the machine-tool industry to determine whether it will support such an exhibition as being of service to it. If the response is favorable, it is probable that the next National Automotive Production Meeting will be a doubly attractive one and will draw one of the largest attendances in the history of the Society. A distinct effort will be made through the coming year to interest the experts in production matters at the unit and parts factories in presenting papers at the next Production Meeting. It was the opinion of many in attendance at the Cleveland meeting that a large number of papers from such individuals is essential to the full success of the production activities of the Society.

MULTIPLE-SPINDLE MACHINE TOOLS

E. P. Blanchard Describes New Continuous-Type Machine at Production Meeting

Multiple-spindle machine tools and their advantages were discussed in the first paper read at the Cleveland Production Meeting. This paper was written and presented by E. P. Blanchard, of the Bullard Machine Tool Co. He analyzed machining methods as an introduction to the description of the particular machine tools built by the company he represents. Mr. Blanchard said that it is obvious that the operations necessary to produce a finished piece must result in a variety of speeds. Also, the conditions of work for each operation may be entirely different. The single-spindle single-tool unit accomplishes this by a readjustment of all tools and settings on each operation and by changing one operation after another. While cutting efficiency is obtained by this process, the time of accomplishment is prolonged.

Loss of time between the operations is eliminated by using the turret tooling method in combination with side-heads or cross slide arrangements, but the sequence still exists. Multiple-tooling, or a grouping of all of the tools about the work for simultaneous cutting, has been tried to eliminate the sequence, but it has resulted in compromising the machining factors of speed and feed and thus destroyed the cutting efficiency. Complicated tool settings, inaccessibility of the tools for adjustment and difficulty in chucking the work are further disadvantages of the multiple-tooling method, according to Mr. Blanchard. In all the foregoing methods there still exists the inevitable delay of interrupting the machining process for chucking and unloading the work.

It follows from the above line of reasoning that the multiple-spindle principle is the logical one for continuous production. This principle is represented in what is known as the station type of machine tool. In this machine, the piece is the unit of production and the operations to be performed are segregated into groups requiring similar machining factors of speed, feed and tooling. With entirely independent and universal settings of speeds, feeds and tools at each station, the finished piece can be produced under conditions of highest efficiency by setting all tools required for a single cut, or a group of cuts having similar machining factors, at the separate stations of the machine. In this case, the chucking and the unloading is accomplished at one station while the machining operations are in process at the five working stations.

E. P. Blanchard

Another type of machine recently developed by Mr. Blanchard's company employs what may be termed the continuous multiple-spindle process. In this type of machine the operation or the group of operations performed at each chucking is the unit of production, and all operations are accomplished in one complete cycle of the machine. Each work-holding spindle is always opposite its respective tool-head, and all work-spindles and heads are in continuous rotation about a central column. The work is chucked as the spindle passes through the loading sector and while machining is in process through the remainder of the cycle. Mr. Blanchard showed several typical examples of work to which this process of machining can be adapted and gave the time required to complete the operations in each case.

Eccentricity and lateral run-out can be held within limits of 0.00025 in. on the machines described by Mr. Blanchard. He stated in reply to a question that it took demonstrators only 1 day to educate operators on the proper handling of these machines. It was his opinion that the continuous multiple-spindle machine could be installed profitably if it were operated only 2 months in the year. Some firms have found it economical on runs as short as 300 to 400 pieces. The continuous-type machine is especially adapted to the larger pieces of work, say 10 to 18 in. in diameter, and is often used for machining flywheels.

SPUR-GEAR GRINDING AND TESTING

Paper of A. J. Ott Discusses New Machine for Generating Accurate Teeth

Spur-gear grinding and testing was the subject of an interesting and informative paper that was presented by A. J. Ott at the Thursday morning session of the Production Meeting. A generating type of gear-grinding machine was described and a fixture for testing spur gears was displayed

and demonstrated. The paper by Mr. Ott and his son, C. L. Ott, is printed in full on p. 401 of this issue of THE JOURNAL.

Numerous questions were asked the author during the discussion period and the answers to some of these are of interest. He stated that from 0.003 to 0.005 in. is removed at the pitch line of the teeth by the grinding operation. The grinding time required on the average transmission gear is from 5 to 6 sec. per tooth. Using a grinding wheel 30 in. in diameter permits the machine to grind gears up to a face width of 2 in. Both the driving and the coasting faces of a spur gear having 33 teeth can be ground at the rate of 55 to 60 gears per day. With ordinary care grinding 60 teeth without dressing the grinding wheel should be possible. The wheel should not be dressed while a gear is being ground.

From 0.005 to 0.010 in. backlash is all that is necessary in the opinion of the authors. An accuracy of tooth profile within limits of 0.00025 in. can be attained with the gear-grinding method. A labor cost of 50 cents will be added to the total cost of an average passenger-car transmission if all the important gears are ground. Gear grinding not only accomplishes a reduction in the gear noise of automobile transmissions, but it saves tear-downs after assembly and tends to increase the durability of the gears because of their smoother running. Teeth having contours of a modified involute form can be ground just as readily as those following the accurately developed involute.

W. Hadley, the English representative of an American gear-grinding machine builder, stated that grinding of transmission gears was fairly universal practice in England.

A. J. AND C. L. OTT

European motorists shift gears frequently and they insist upon reasonably quiet operation of the first and second gears. Some British companies run-in gears with lapping compounds, but the great majority are now employing the machine-ground gear as a means of reducing the transmission noise.

PRODUCTION GRINDING DEVELOPMENTS

Production Meeting Paper and Discussion Reveal Demand for Mirror-Like Finish

Recent developments in production grinding were described and illustrated in the last paper in the Thursday morning session of the Production Meeting. This paper was prepared and read by Oscar A. Knight, of the Norton Co.

O. A. KNIGHT

It will be found printed in full on p. 387 of this issue of THE JOURNAL.

Following the reading of the paper, Mr. Knight answered numerous questions put by members of the audience and the following paragraphs summarize his answers and the general discussion. Increasing the diameter of crankshafts does not permit the removal of steady-rests in crankpin grinding-machines, in Mr. Knight's opinion. In some instances these heavier shafts, although more rigid, tend to vibrate during the grinding operation and this will be eliminated if the work is properly backed up by a steady-rest. The balancing of grinding wheels is receiving constant study and no balancing devices will probably be needed on the grinding machines of the future because the wheels will be made so as to remain true throughout their life.

The limits for alignment of the pin-axis and shaft-axis should not be greater than 0.002 in. or they will retard production, according to Mr. Knight. Mention was made of one firm that buffs all crankpins after grinding, the buffing being done in the opposite direction of rotation from that followed by the crankshaft in its bearings. This is done on the theory that the buffing operation removes small metallic particles and smoothes the surface down so that irregularities in the pin surface will present smooth edges to the babbitt bearing and eliminate any tendency to pile-up and score it. Buffing, if correctly performed, improves the surface of the average shaft after it has been finish-ground. It will not correct out-of-roundness of the ground shaft, however, but will follow the basic surface that has been formed in the grinding machine. Grain lines can be eliminated if the grinding wheel is arranged to oscillate a slight amount; this oscillation need not be more than ⅛ in.

A tendency toward a greater application of the centerless method of grinding exists, in Mr. Knight's opinion. Just as great accuracy can be secured from the centerless machine provided great care is taken in its use, however the full production advantage of centerless grinding will only be secured if the limits are fairly wide. Asked whether he favored the use of ball or roller bearings to support the main spindles of grinding machines, the speaker replied strongly in the negative. Chatter and mottle marks nearly always become more pronounced in work that is done on grinding machines that use ball or roller bearings in this place. Chatter marks were reduced by substituting a chain for a gear drive in the machines described by the author, who stated that inaccuracies in the gears were responsible for the chatter and intimated that gears might be satisfactory if accurately made.

Wide-wheel grinding is limited at present to a maximum of 9¾ in. and Mr. Knight was asked the reason for this limitation. He replied that it is entirely a matter of properly supporting the grinding wheel. Placing a bearing on the outside or the inside of a wide wheel is not good practice because it would be necessary to remove the bearing to change the wheel and this would affect the alignment eventually.

Arthur C. Pletz, of the Morris Machine Tool Co., Cincinnati, described a method of buffing crankpins with a machine very much like a grinding machine. This machine uses a rotating hard-felt wheel instead of the grinding wheel. This wheel is covered with an abrasive preparation and is kept in contact with the rotating crankpins for only a few seconds. It is used to get a mirror-like finish on the surface of the crankpins after they are ground and is not intended to correct any errors in the contour of the ground shaft. Less

LABOR PSYCHOLOGY AND PHILOSOPHY

Interesting Views Expressed in Production Meeting Paper Read by W. F. Jameson

All factory executives are familiar with the time-worn expression "human element errors." The psychological causes for the worker's state of mind that results in the making of [illegible] were here studied by W. F. Jameson, chief [illegible] of the Cleveland Automobile Co., and were the subject of the paper that opened the Thursday afternoon session at the Production Meeting in Cleveland. Mr. Jameson's paper will be found printed in full in this issue of THE JOURNAL on p. 366.

W. F. Jameson

President Alden, who presided at this session, opened the discussion by telling the experience of one steel manufacturer who believed that the inauguration of the 8-hr. day and the consequent studying of means to improve the welfare of the steel-worker would result eventually in lowered rather than raised production costs in the steel mills. Mr. Jameson was asked how he rewarded the conscientious worker who showed evidence of concentrating and thinking on his job. He replied that the worker must be sold on the fact that his own satisfaction with his work is his reward. Of course, this thought cannot be sold to all workers but must be possessed of some intelligence to grasp the significance of it.

Good salesmanship is essential to the successful introduction of Mr. Jameson's plan of worker-interest stimulation. His experience has been that the men in the shop can be interested to the idea that their job is their school, but good [illegible] are required to capitalize them. Once the employer has grasped the idea, its fruitfulness depends upon the attitude of the man himself. To make a start in a given plant, the best way is to select a few men whose reflection of interest [illegible] the chances of successful application in their case is at least an even one.

FRANKLIN CONVEYOR EXPERIENCE

H. P. Harrison Unreservedly Describes Unsuccessful and Successful Installations

Materials-handling equipment is to be an important phase of manufacturing efficiency. This was evident at the Production Meeting as was observed the attentiveness of the audience that listened to the paper read by H. P. Harrison, of the [illegible] Mfg. Co., on the application of conveyor

H. P. Harrison

equipment in the factory of that company. The conditions that determine whether power-driven or gravity-actuated conveyors should be used were discussed. Mr. Harrison illustrated his paper fully and showed types of conveyor equipment used for handling cylinders, transmission cases, rear-axle housings, front and rear-axle assemblies and for the final assembly of complete chassis and bodies. His very interesting paper will be found, printed in full, on p. 357 of this issue of THE JOURNAL.

Reference to Mr. Harrison's paper will show that he did not explain how the cylinder carriers were returned to be used again. This point was covered in his answer to one of the questions presented in the discussion. He said that the carriers are returned on the downward travel of the outside elevator chain, fed back into the line at a point below the delivery section of the gravity chute, then picked off automatically at the basement level and dropped in a pile at that point. About $125 has been saved daily by the installation of conveyor equipment in the Franklin plant. All the assembly conveyors are in motion when assembling operations are being performed. They are driven by adjustable-speed motors that can be set for any desired daily production.

Franklin cylinder castings come to the conveyor from the foundry in fully sand-blasted condition. They are cleaned at the end of the machining line in an atomized-steam kettle. This operation supplies enough heat to the casting so that it dries itself and is then given a coat of paint. No auxiliary method of moving parts in case of conveyor breakdowns is provided in the Franklin installation. Parts are trucked in an emergency of this sort. No serious delays have been experienced from conveyor failures and it is possible to make minor repairs and carry on conveyor maintenance-work at night, since the Franklin shop operates on the 8-hr. day.

GROUP PIECE-WORK WAGE PAYMENT

System in Use at Chandler Plant Is Described in Paper at Production Meeting

Production engineering divides itself into three general classifications, material, labor and tools. To say that some of the most perplexing manufacturing problems are those connected with the labor classification is not exaggeration. For this reason labor control and wage-payment systems have a place on any program of production papers that claims to be at all comprehensive. In the case of the Cleveland Production Meeting it was noticed that more questions were asked about Eugene Bouton's paper on Wage-Incentive Systems than possibly any other topic on the program. This paper sets forth a system of individual and group piece-work wage payment that is in successful use at the plant of the Chandler Motor Car Co. It will be found printed in full on p. 380 of this issue of THE JOURNAL. Some of

EUGENE BOUTON

the important questions and answers raised at the meeting are reported in the following paragraphs.

Labor turnover has been materially reduced by the adoption of the wage plan described by Mr. Bouton. It has stimulated collective effort, the men try to help one another and attendance records are much improved. All employes receive an hourly rate and after the group price is set they are pro-rated on that hourly basis. If a man's hourly rate is raised, the cost is not increased, but he gets a higher prorated share of the group's earnings. If certain members of the group apply themselves more conscientiously than others, they should be rewarded for their effort. Slow and lazy workers are frequently run out of a group by the other workers in it, but there is seldom any trouble between the men when all are industrious.

Daily earnings of the men in each group are reported to them by their foreman. He receives a copy of the group piece-work report and can give the workmen the information from that. After the group has been in operation for some time the men are able to gage their earnings readily without making inquiry of the foreman. Two days are allowed for a new employe to accustom himself to the work in the group to which he is assigned. If he is unable to come up to the required speed, he is taken out of that group. Determination of the rating of the men in a group is left in the hands of the foreman. Time studies assist him in making this determination but he must use considerable judgment also.

Mr. Bouton was asked what he considered a fair percentage to add to actual time studies as an allowance for fatigue and contingencies. He replied that this would vary between 10 and 20 per cent, depending on the particular job. Machine-tool builders make a practice of allowing 20 per cent. Piece rates are not cut in the event that they are set too high. The only reason for cutting rates would be a change in tooling or a change from one type of machine to a more efficient one. If the worker makes more than it was intended he should make, the condition is simply put up with. Fair wages for a given locality must be determined by the management of the company and the base rates set from that by the planning department.

Allowance for scrap is largely dependent upon the nature of each job. Where tolerances demand a high degree of accuracy, an allowance of 2 per cent might be necessary. When the scrap deduction is made from the group, only the labor and the time expended on the work is considered; no deductions are made for material scrapped. The system described by Mr. Bouton guarantees the workman a minimum hourly rate, but if the worker is unable to exceed this he is not an economical producer. He should earn the base rate or turn out the number of pieces specified on the route sheet before he is considered efficient.

In the 6 months' application of the Chandler system it has been noticed that inspection expense has decreased because payments are made only on the accepted pieces. If any deductions are made, the men realize that the loss applies to the entire group and they soon aid one another in reducing the number of rejected pieces. Mr. Bouton believes that any group system of wage payment effects a reduction in inspection expense. He allows only 1 per cent for scrap on the average.

When one member of a group receives an increase in his daily rate, the earnings of the other members of the group are slightly reduced. This has never caused any trouble within the group, according to Mr. Bouton. If a member of the group is tardy 1 hr., he loses that proportion of his prorated earnings and this amount is credited to the remainder of the workers in the group. So-called speed-experts or pacemakers are never injected into groups to speed them up. Sometimes the efficiency fostered by the group plan leads to the men earning much more than was anticipated, but that is a contingency that must be accepted with any group plan.

Inspection work in the Chandler plant is done on a straight-day-work basis. This is also true of the tool department.

No provision is made under the group piece-work plan for men who may be absent. If a group consists of 10 men and 1 man is away, the work is turned out by the remaining 9 men and all the earnings divided among them. If the men in a group are dissatisfied with a new man, they appeal to their foreman who replaces this man with another who is acceptable to the group. In this way the men may be said to have a voice in the selection of the workers making up their respective groups. Mr. Bouton does not find that individual incentive is lacking in large groups, say of 90 men. They are all anxious to help one another and whenever congestion at any point occurs the men assist the worker who is behind, without receiving any order from the foreman. The hourly rates guaranteed under the plan described are lower than those paid for straight day-work.

J. C. W. Smith, of the Willys-Overland Co., said that his company had applied the group system, but paid all men in the group the same wages. He favored piece-work wage payment instead of the standard-time system because the worker could figure out his own earnings more readily and this avoided misunderstanding. He referred to the paper given by E. K. Wennerlund[2] at the Detroit Production Meeting and said that he considered it had one fault. This is illustrated by the case of two men, both grinding axle-shafts, who receive different amounts of money at the end of a pay period although both produced the same number of pieces. If the supply of labor in the market is ample, under the day-work system men can be hired at the lower rate on axle grinding and the man on the higher rate let go. The Overland factory makes a practice of guaranteeing piece-work prices for a year and standing by them even when errors are made in the original setting. This policy has resulted in at least a 25-per cent increase in the labor efficiency in the Overland plant.

Mr. Bouton agreed with the criticism of the group-bonus plan. He said that there is no reason why one man should draw more money than another just because they are on the same job. The piece-work plan is superior for group incentive because it assures a reward to each man in a measure proportionate to his efforts.

[2] See THE JOURNAL, November, 1922, p. 402.

FUNCTIONALIZED TIME-STUDY METHODS

Production Control System of the Corona Typewriter Co. Explained in Detail

PERCY S. BROWN

At the Scientific Management Session on Thursday evening, Percy S. Brown, works manager of the Corona Typewriter Co., presented a comprehensive statement of the production control methods of that company. The paper was, of course, specific and obviously the preparation of it had required a great amount of work. President Feiss, of the Taylor Society, who was present at the meeting, referred to the fact that F. W. Taylor always refused to speak less than 2 hr. on the subject of management and maintained that the only way to present any matter of real importance connected with the subject is by submitting concrete examples.

It was clear from the evidence, Mr. Brown submitted that the business of his company is well organized and controlled. It is helpful to have designers of automotive apparatus consider what is necessary in the analysis and the design of a business. The principal factor in the lowering of the price of a final product is the reducing of the cost of the operations involved in its fabrication. Of course, wide distribution is essential to the carrying out of the

Introduction of System

The functional system of factory management was introduced at the Corona plant in 1917, the change from the so-called military type of organization being made instantly. The principal thing in the conduct of a factory being co-operation, no new system, however efficient, can be reduced to practice in a short time without the personnel in general knowing of its merit.

Mr. Brown's paper was based upon the premise that, except for the elements of size and weight, the problems involved in the production of automotive apparatus are not dissimilar from those encountered by the manufacturers of portable typewriters. What is known as continuous manufacturing is prevalent in these industries. The Corona Typewriter Co. has 1025 parts to manufacture, 600 of these differing in kind. In connection with these there are about 2500 manufacturing operations, these including all assembling but not inspection; there are about 2000 inspection operations. All operations of a similar nature are concentrated as far as possible in the same department. All factory control is highly functionalized, the plan advocated by F. W. Taylor being followed to a considerable extent.

In preparing the paper for presentation to the Society, Mr. Brown asked the head of each of the Planning Department Divisions to submit a statement of the respective methods followed, together with copies of all forms used. The head of the Planning Department checked the report of each of the divisions and had revisions made when necessary. As editor-in-chief, Mr. Brown combined the reports into the paper. In functionalizing the work, the various subdivisions or sections were placed under the direction of highly trained men of engineering experience or qualifications. The Methods Division was divided into five sections, as follows: (*a*) assembly, (*b*) machine, (*c*) gate checking, (*d*) salvage and (*e*) record. The work of the engineers in (*a*), (*b*) and (*c*) is essentially of a non-routine character, the men being primarily free lancers in their work. The chief duties of these engineers are to establish efficient methods of manufacture of new parts, to improve methods in use, to test and approve production tools and the like, to investigate complaints, to test materials and to standardize all methods, tools, materials and supplies. The Salvage Section, besides handling the disposal of scrap, determines on the scrappage of parts after studying each case and determining whether it is cheaper to repair or to scrap.

Essentials of Reports

In the Corona plant, the experimental department corresponds to the engineering department of an automotive factory. Mr. Brown said that all formal reports made must contain, in addition to the subject and the specification of what is to be done and how, an outline of the available knowledge relating to the subject, a statement of the object in view, an historical sketch of previous investigations and findings, a description of the procedure in the investigation and conclusions and recommendations. The Methods Division keeps in close contact with the purchasing department in matters involving technical points. Mr. Brown said that this is an important matter. The initiative in securing better or cheaper materials or supplies is not left to the purchasing department, but may be in any part of the organization.

In connection with time-studying, Mr. Brown explained that after the demonstrator has had sufficient practise to gain a rhythm of motion, the observer begins the timing of an operation. The operation is divided into as many elements or movements as can be timed effectively. Any time per movement that varies 35 per cent or more from the time selected as the correct time is considered abnormal. In speaking of one operation, Mr. Brown pointed out that 2-per cent personnel, 3-per cent fatigue and 3-per cent machine and tool delay-allowances were made. Two 10-min. rest periods also are provided. The operators are assured that the standard rates and time issued will not be changed unless a radical change in design, machine or method is made. An inexperienced operator is allowed a learning period, according to each case. The use of a daily efficiency record has proved of value; the operators are not only interested in the pay they receive but take pride in achievement.

As frequent changes are made in the design of parts, it is essential that inventories be maintained at the lowest possible minimum and that the stock of material, parts in process and finished parts be well balanced. In the typewriter industry a month's supply of a small part can be turned out in less than an hour. This means that continuous work on any single operation is rare. Most of the parts are produced in lots of 5000 and 10,000. A definite balance of finished parts is kept as a reserve against emergencies, this being in most cases the quantity used in 3 weeks' production.

Control being the vital feature of planning, the control-board of the Corona company is a graphic combination of the parts ledger and the stores ledger. This is a large board around which strings are tied vertically, a pair for each part. The board provides a graphic daily posted inventory. Mr. Brown submitted a chart or form for each important step in the practice of the factory. He emphasized the fact that the only way to understand fully the methods in use is to study these forms. Mr. Feiss said that the value of the methods installed at the Corona factory could be appreciated only after a visit to the plant. One general observation that Mr. Brown made was that orders are pulled and not pushed through the factory. An important condition is that no parts are filed or sawed by hand, all of the component elements being interchangeable under the system of standardization maintained. Inasmuch as all materials, supplies, type, and key cards are checked through a continuous inventory so arranged as to be completed every 6 months, no other inventories are taken. The Stores Division is expected not merely to keep an adequate supply of all items under its control but also to assist in keeping all stores at the minimum. Mr. Brown said that the whole system which he described is being maintained at a minimum of inconvenience, without causing any shutdowns and with considerable smoothness and economy.

STANDARD VERSUS SPECIAL MACHINES

Quantity Output Possibilities of Each Type Discussed at Production Meeting

Maximum production from factory equipment means versatility in the possible application of certain machines and reasonable adaptability for all machines. Without these qualities the equipment cannot turn in the greatest earnings to the manufacturer. At the Production Meeting, held last year in Detroit, there was started a discussion of standard versus special machines. This question is again taken up in the paper on standard machines for quantity production by Ralph E. Flanders, of the Jones & Lamson Machine Co., who is also president of the National Machine Tool Builders' Association.

After reviewing briefly the question of merits of standard versus special machines as presented at the 1922 Production

Meeting, Mr. Flanders considered, from the machine-tool builders' viewpoint, the problem of so designing and building machine tools as to retain the favorable points of standard machines without sacrificing the advantages of special adaptability and economy characteristic of the ideal special machine. Two possible solutions of the problem were cited; (*a*) building semi-special types of machines from standard units and (*b*) building standard machines with universal foundations upon which highly specialized tool equipment can be mounted. The turret lathe and the automatic lathe, built by the company with which the author is associated, were described and illustrated as representative examples of the two types above mentioned. He enumerated the essential features of the design of these machines and then outlined briefly the advantages of standardized equipment. In the course of his paper Mr. Flanders mentioned the fact that machine-tool builders are now introducing systems of quantity production that are very similar to those already in force with the automotive manufacturers.

R. E. Flanders

In conclusion the author suggested that, as part of future Production Meetings of the Society, one or two sessions devoted to the processing and tooling for a single typical part, such as a two-part differential housing or a crankshaft, be arranged.

The discussion brought out more clearly a number of important details of design as well as numerous examples and specific applications of the machines to particular jobs. K. L. Herrmann who presided at this session, called the attention of the members to the importance to the tool designer and maintenance man of the standardization of tool bits as used on the machines described. He also recalled the fact, as previously mentioned by Mr. Flanders, that in some instances the machine capacity is greater than the capacity of the article to withstand the strain of production; this raises the question of suitable design of parts that can utilize the productive capacity of the machines.

HOW TO USE THE SCLEROSCOPE

Instrument's Inventor Says That Methods of Application Should Be Standardized

Hardness determination has long held a place of great importance among engineering inspection tests. It presents problems that are not as yet completely solved, but that still attract the interest of all practical engineers. Albert F. Shore, president of the Shore Instrument & Mfg. Co., inventor of the scleroscope bearing his name, has done much toward solving this problem, and the Society considered it a privilege to have for the Production Meeting his paper on the Standardization of Methods of Applying the Scleroscope that is printed on p. 409 of this issue of THE JOURNAL. Pursuant to the author's desire, L. C. Hill read the paper while Mr. Shore handled the discussion. Several points raised by the Iron and Steel Division of the Society's Standards Committee were discussed by the author. As regards the plumbness of the instrument at the time of hammer drop, it was stated that in addition to the errors in the drop caused by holding the instrument out of plumb, the difficulty of having fluctuations in the readings was encountered, thus making a comparison of the results difficult. A marked effect was said to result from lateral vibrations. It was also stated that the effect of surface roughness of the specimen is not as great as is usually supposed, that careful polishing is not necessary and that under proper conditions of test the scale on the surface of steels in the soft condition has but a slight influence on the readings of the instrument. Other topics included the condition of the diamond point, the effect of mass of the test-specimen, extreme under-weights, inert and over-weight masses, the effect of hardness on mass, the thickness of the test-specimen, testing near specimen edges, the effect of curved surfaces and how specimens are mounted. One of the most interesting parts of the paper dealt with comparisons between Brinell and scleroscope hardness determinations. A conversion chart, tables and other material bearing on this subject were presented.

A. F. Shore

The discussion covered a wide range of questions relating principally to the methods of using the scleroscope and mounting the specimens. With regard to the effect of weather conditions on the indications of the instrument, Mr. Shore stated that no effect was noticed unless actual drops of moisture collected in the tube and thus interfered with the hammer travel. It was also pointed out that for special tests, such as those on carbon, a specially-fashioned diamond-point is necessary.

MEASURING OUT-OF-ROUNDNESS

Governing Factors and Inspection Methods for Various Types Outlined

In his paper on Factors Governing "Out-of-Roundness" Measurement, A. H. Frauenthal, chief inspector of the Chandler Motor Car Co., dealt with so-called "regular" types of "out-of-roundness", that is, with high and low spots following some mathematical continuity. He linked certain types of out-of-roundness with the types of machine on which the work was mounted. For example, on work that comes out-of-round from a centerless grinding machine, the high spots and low spots appear in multiples of three. This the author attributed to the three points of pressure in the machine, namely, the grinding wheel, the feed wheel and the work support. The importance of properly selecting and using gages and measuring instruments for checking out-of-roundness of various types was mentioned. The topics discussed in this connection were the three-point measuring system, errors of the V-block method, elliptical objects in a V-block, other methods for checking elliptical forms and indicator-reading correction. In conclusion the author suggested the following three items as worthy of consideration by the manufacturers; (*a*) a flat measuring-point large enough to reach the major diameter when it is off-center with the measuring-point due to ellipticity, (*b*) a revolving characteristic of the measuring-point to pro-

A. H. Frauenthal

COMPANY ORGANIZATION FOR PROFIT

Principal Topic of the Address Delivered by R. H. Grant at the Production Dinner

In addressing the members at dinner on Friday evening, R. H. Grant, general manager of the Delco-Light Co., took as his subject Management. In his introductory remarks he said that "scientific" management is apt to result in overlooking main issues, and that the best combination is common sense and horse sense.

Mr. Grant reiterated what he stated emphatically at the Annual Spring Dinner of the Society in Chicago, namely, that company organization consists of four divisions devoted to engineering, finance, manufacturing and sales, respectively; the prime purpose being to produce a return on capital exceeding that available from investment. There is a tendency in a highly specialized business for the men in the different divisions to become so wrapped up in their immediate work that they overlook the real reason for the existence of the business.

Mr. Grant divided management into two classes: (*a*) strong general management, that effects hard enough work in each department; (*b*) management that selects as subordinates men who are not only qualified as specialists but able to understand the main problems of the company. He said that any business can be successful when well conducted but that the best results are secured by virtue of the cleverness with which plans are carried out rather than of the merit of the plans themselves. The proper work of the financial department in connection with the granting of credits, for example, to keep the loss from bad debts sufficiently low and still permit the total amount of business to increase. The men in the different departments should exert their intelligence in the highest degree possible. The salesman should cooperate with the financial department to secure business according to approved business principles. If the chief engineer understands what article will secure the greatest sales, it is his duty to design this. There must be coordination of interests between, as well as clever work by specialists in, all the main divisions of the business to make the whole general scheme adequately profitable. The production man should not be autocratic but give due consideration to the experience and the ability of others in the organization. There must, of course, be a clear understanding throughout the company of what the undertaking in hand is, how much the investment is and what and how much must be produced. The program must be decided upon 3 months in advance of the beginning of a given manufacturing year. Then calculations can be made as to how much direct labor will be needed, what overhead-expense burden can be assumed and how extensive a sales organization is needed. Those in the selling field should be told what they must do to meet the various quotas involved in the plan. Maintenance expense must be analyzed and advertising cost decided upon. The general manager must watch constantly the degree of progress made in each of the departments. Minimum figures of performance for the future should be set for the length of time feasible and in such amount that the men concerned will endeavor to exceed them. Forecasting is an essential part of good business. The carrying out of a definite 4 months' schedule usually means more profit than is gained in production according to a variable monthly program. A whole year's work should be accomplished without interruption. The type of a business determines how far in advance a production schedule can be planned. The most gratifying results are secured when many minds are concentrated on one specific purpose. All are in business to attain the highest personal success possible. A man can help himself best by contributing something that redounds to the greater profit of the company.

President Alden was toastmaster at the dinner. Jack Raper, humorist of the Cleveland *Press*, amused the members by showing that prohibition is too serious a thing to joke about and making observation on other live issues of the day.

R. H. Grant

FOUR CLEVELAND FACTORIES VISITED

Members Inspect Automobile, Truck, Steel and Malleable Castings Plants

About 100 members and guests attended the factory visits that were a part of the Cleveland Production Meeting. Orrel A. Parker, chairman of the Factory Visit Committee, arranged to have motorbuses and cars convey the members in groups to the several factories and dispatched these on a prompt schedule. The factories visited included the American Steel & Wire Co., the Chandler Motor Car Co., the National Malleable Castings Co. and the White Motor Co.

Visitors to the plant of the American Steel & Wire Co. saw large rolls squeezing out thin sheets of hot-rolled steel that were to be stamped out eventually in huge presses to form the panels for automobile bodies. Bar stock of various shapes and sizes was also being passed through the mill at the time of the visit. The members were high in their praise of the courtesy extended them by the factory officials.

Apparently a majority of the members were interested in automobile construction, for the visit to the Chandler plant attracted over 60 men. They were transported to the factory in cars provided by their hosts and were given a courteous welcome by J. R. Hall, vice-president and factory manager. Responsible factory executives showed the visitors every nook and corner of the large Chandler plant, the crowd being divided up into groups of four or five each. Great interest was shown in the modern conveyor systems used in the handling of the Chandler product both in the carrying of the parts and for the assembly of the bodies and complete vehicles.

One of the largest continuous annealing furnaces in the

world was seen by the members who visited the foundry of the National Malleable Casting Co. They were very favorably impressed by the foundry methods in use by this organization.

The visit to the White factory was added as an extra feature because many of the members desired to inspect this plant. Some 30 men availed themselves of this opportunity to see one of the largest motor-truck factories in the world.

Appreciation must be recorded here of the courtesy and hospitality of these four Cleveland factories and their officers. In every instance, the visits were handled expeditiously and questions were answered courteously and fully.

A FEW WORDS OF GRATITUDE

Meetings of the Society are successful largely because of the voluntary efforts of those of its members who take an active part in the preliminary arrangements and the conduct of the social and professional programs. In the case of the Production Meeting at Cleveland, Oct. 25 and 26, unusually able and earnest cooperation was shown by the officers and members of the Cleveland Section. John Younger deserves mention for the assembling of several energetic committees and instilling their members with enthusiasm in the meeting's work. Orrel A. Parker arranged all of the visits to the Cleveland factories and organized the transportation in an effective way.

Much favorable comment was voiced by the visiting members on the congenial and helpful work of the large Reception Committee that greeted the men as they arrived, aided them in registering and assisted in running the several meetings and the dinner on schedule time. This committee was headed by H. J. Monson and consisted of E. W. Austin, R. S. Begg, M. Bleiweiss, T. V. Buckwalter, W. T. Cogger, A. M. Dean, E. E. Eyeman, C. A. Michel, R. J. Nightingale, Clyde Pelton, A. J. Scaife and Arthur Skinner.

H. J. Monson

O. A. Parker

TWO OF THE COMMITTEE CHAIRMEN WHOSE EFFORTS WERE LARGELY RESPONSIBLE FOR THE SUCCESS OF THE MEETING

It is also appropriate to record the Society's appreciation of the interest of the authors in preparing and presenting their valuable papers. Acknowledgment is made of the cooperation of the Taylor Society in securing a paper from one of its members for presentation at the Scientific Management session. Last, but by no means least, the Meetings Committee of the Society deserves mention for its continued good work.

BODY NOMENCLATURE

THE following editorial, which is reprinted from the October, 1923, issue of *Autobody*, will be of interest in connection with the recent action of the Passenger-Car Body Division in approving of the term "coach" as a body designation. An article outlining the action taken will be found on p. 417 of this issue.

The National Automobile Chamber of Commerce, through its service division, has suggested to the Standards Department of the Society of Automotive Engineers that a standard name be selected for the enlarged coupes put out by Hudson, Essex, Nash and others under the names of "coach," "brougham," "carriole," etc. We do not know whether this is intended as a joke by the car builders, or whether the service departments are having to bear the brunt of the confusion and have arisen to protest against the foolishness of calling a coupe a sedan, and vice versa. If it is a protest against the confused condition of our nomenclature, that protest should be lodged with the car builders whose sales departments have been the chief sinners.

The abolition of "pleasure car" was a long-drawn and costly struggle, if measured in luxury taxes, and this old-time offender has not yet been completely estopped. Until the sales and sales-promotion departments clean house, there is little hope of clearing up body nomenclature.

At the time the present S. A. E. nomenclature was adopted, no definite names were selected for the so-called "coach" and the "close-coupled sedan" because it was then felt that these were more or less ephemeral types. This lack of leadership, however, has resulted in much confusion in the names of the intermediate-sized closed bodies. One now hears of "four-door coupes" and "close-coupled sedans" as the designation for the same body, and as for the two-door five-passenger model, with individual front seats and a rear cross-seat, it is called a five-passenger coupe, a touring sedan, a brougham and other names too numerous to record.

The first-mentioned type of body arranged for four or five passengers appears in a fair way to become the standard size of sedan bodies. It is a mystery to us why these four-door closed models cannot be satisfactorily designated as five- or seven-passenger sedans. With reference to the two-door models, the naming of these has run wild for so long that there will be much inertia to overcome in establishing any one of the existing names unless we adopt "coupe" already used to a considerable extent with a qualifying designation to indicate the seating capacity. "Coach," "brougham" and "touring sedan" would seem to be disqualified for the reason that these terms are already used and needed for other vehicles.

THE AMERICAN WORKINGMAN

THE American workingman is better off today than he ever was before. During the first half of 1923 increased pay and a higher level of hours worked resulted in substantially increasing earnings. The comparatively small increase in the cost of living for the same period materially increased the weighted or "real" earnings, which reached levels well above those attained during the months of so-called peak wages in 1920. In June, 1923, the "real," or weighted, hourly earnings were 40 per cent above the 1914 level and the weekly earnings 35 per cent higher.—*Economic World.*

THE UNITY OF SOCIAL INTERESTS

Since the time of Malthus the achievements of scientific research have given a larger view of the potential command of man over the resources of nature. Institutions are demonstrating that agriculture is a science, the possibilities of which may be limitless. Moreover, the improvements in methods of transportation since the time of Malthus have been revolutionary, thereby facilitating both the spread of population over unsettled areas of land and the transportation of food products from the new countries to the old, where the problem of food supply is pressing.

So influential have been these changes that the Malthusian doctrine in recent years have come to have not much more than a historical interest, and yet it contains a truth of fundamental importance. The population is rapidly increasing, the area of land is limited, and in the long run it is only by increasing mastery of the secrets of nature, more efficient methods of cultivation and a higher intelligence throughout the body of the population that the conditions depicted by Malthus can be averted.

We have a vast area of land yet to be brought under cultivation, but most of it is either of inferior quality or will require a large expenditure of labor to fit it for use. It is in competition with these lands that Iowa farms have been bringing $200 and $300 per acre.

Every census has shown a smaller percentage of our people engaged in agriculture, and at the last count less than one-third were actually living on farms. This reduction of the proportion of the population upon the farms, because a smaller number are able to supply the required amount of farm products, is not something to be regretted. A great development of the other industries has been made possible and has brought into common use a vast number of comforts and services that our fathers knew nothing of. It has raised the standard of living for the population, but this is mainly because we have been able to spread our farming operations over more land. I am not sure that the yield per acre on the whole has increased, and to offset a growing population we need an increased yield per acre without higher costs. I doubt if the fertility of the soil is being maintained. I believe that the quality of our live stock has been improved, thanks to the leadership and the influence of the agricultural colleges and the labor of many other devoted men who have been identified with the industry. But after all is said, the ability of our agriculture to keep production up to the demands upon it has been dependent up to this time mainly upon spreading over more land, and that means to lands of lower productive capacity than those in use heretofore, and higher costs unless we improve the methods. And all experience shows that it is a slow task to change the habits and customs and raise the average productive capacity of a great mass of people.

We know that the prices of all natural products have been increasing and were on a rising scale even before the phenomenal increase that resulted from the war. Over against these tendencies we have the influence of improvements that may be made in the methods of production and distribution, the results of invention, of scientific research and of the accumulation of wealth in the form of productive equipment. The net result of these two sets of influences determines whether society moves forward or backward. Unless we develop greater harmony and efficiency in industry and learn to use wisely some of the inheritance of knowledge and of industrial equipment greater than we [illegible] Country and left our successors with a greater population to face harder conditions of life than we have known ourselves.

There is more gain for the members of any group or class in promoting the efficiency of the organization as a whole than in attempting to promote the interests of their own group by means that impair the efficiency of the whole. There is a just relationship between all the branches of industry and business, the maintenance of which is worth more to everybody, by promoting general prosperity, than any special advantage can be worth.

The highest state of prosperity results from a balanced state of industry. We know that to obtain the best results in an individual industry all departments of the industry must be in balanced relations to each other; and so there is a normal equilibrium throughout industry that must be maintained to have prosperity. All business in the last analysis is simply an exchange of goods and services; and this being true, all branches of industry must be so related that the products of every industry will be absorbed and consumed by the people in the other industries. This means that their interests, instead of being antagonistic, are necessarily interlocked and dependent upon each other. An injury to one affects them all.

Before the war a great volume of mutually beneficial international trade had been developed. Europe was the center of the world exchanges. It was constantly receiving great quantities of foodstuffs and raw materials from all parts of the world and paying for them by sending out manufactured goods. The war disrupted that trade. Russia was an important factor in that trade with Western Europe, and Russia has been practically eliminated for the present. It might be thought, at first, that since Russia was the principal competitor of the United States in the exportation of foodstuffs, the disappearance of Russia would be beneficial to the farmers of this Country; but we know that our farmers are not so well off as before the war. That is because the disappearance of Russia as a market has injured the manufacturing industries of Europe, so that their purchasing power is less than before. The whole situation is too disorganized for anybody to gain by it.

I think most of our troubles are due to the fact that we have developed the industrial organization beyond the understanding of the ordinary man. He does not know his own part in it; he does not realize the benefits that he gets from it; and you cannot expect men to be loyal to something they do not understand.

The greatest obstacle to social progress is the want of understanding and of the spirit of cooperation that depends upon understanding. The system under which men give their lives to the pursuit of knowledge or the development of skill in special lines is dependent upon the spirit of cooperation and of fair play. It depends upon mutual confidence and good faith. We must trust each other or go back to the primitive conditions of life.

It is a strange fact that the world is haunted with a fear of over-production, although there is scarcely a person in it whose wants are fully satisfied and the great mass of the people are in want of common comforts. The truth is that over-production is inconceivable. Unbalanced production there may be and frequently is, this Country having suffered from it in the last 2 years; but over-production there cannot be while human wants are unsatisfied.—From an address by George E. Roberts at Iowa State College of Agriculture.

TRANSPORTATION

FOR the decade ended with 1910, highway transport commanded about one-third of the capital put into railroads; in the decade ended with 1920, it commanded four times as much capital as railroads, that is, approximately, $16,000,000,000, out of a total for all transportation of $23,000,000,000, against $4,000,000,000 for railroads. These facts indeed challenge attention. Although the gross railroad investment per ton handled has decreased from about $17 in 1880, to about $8 today, little reduction has been made within the last 20 years, in spite of greatly increased traffic and efficiency, a fact that seems to indicate that the majority of the new capital has gone into expensive terminals, which is also indicated by an analysis of the track-mileage additions through the years.

Transportation is the second industry in the United States, costing, approximately, $50,000,000,000 to build, which is about twice the National debt. It is next to agriculture, $80,000,000,000, and exceeds manufacturing, $45,000,000,000. In general terms, the cost ratio is approximately 2:2:1 for railroads, highway transport and other agencies respectively. This great transport plant has grown from $14,000,000,000 in 1900 to $26,000,000,000 in 1910, and $50,000,000,000 in 1920. Railroads held the stage from 1900 to 1910 and highway transport and shipping since 1910. It would be a wise prophet who could foretell the future cost of highway transport.

If all transportation increased only as fast as the railroads, by 1940, $25,000,000,000 of new capital will be required at the minimum, with probably $25,000,000,000 more for replacements of depreciable property retired. It is incredible that railroad development will recede. It is more likely that other transport will advance, so that these total figures are probably much too conservative. Does not the fact that the cost of the highway-transport plant has grown to nearly that of the railroads and possibly 40 times that of inland waterways construction emphasize the need of a broader treatment of transportation in the future so as to include not only the "arteries" but also the "heart" and the "capillary system"?

The traffic of the Nation has grown in geometric ratio to the population, while facilities in freight-houses, team-tracks, wharves, transit lines and particularly streets and roadways in the large centers have increased, if at all, only in arithmetic ratio. Thus, railroad tonnage has increased nearly as the cube, and ton-mileage nearly as the fourth power, of the population. Terminal tonnage is probably increasing as the cube of the population, especially in view of the growing proportion of city population to the total in the Country. Motors, however, are increasing far beyond the fourth power of the population and city motors probably as fast if not faster. Nevertheless, in the majority of the cities, practically nothing is being done to survey and develop the capacity of the street system for handling this enormous flood of passenger and freight traffic, for transfer and city destination. Instead, building heights are being forced upward, which only intensifies the problem.

The larger question of future transport will undoubtedly focus in the terminals and some form of physical, financial or operating unification will be evolved to ensure command of the transport situation; that is, terminal evolution in the gateways and large centers offers the greatest opportunity of increased capacity and minimum investment in which ship, barge, motor and trolley, as well as rail, must each play its part. Here, in a large degree, lie the controllable wastes in transportation, both off and on the rail, and it is evident that the maximum efficiency of the arteries of commerce, the rail lines, can never be secured until the heart of the system, the terminals and their distributing agencies, are able to function as they should.

Just before the World War, a survey of less-than-carload freight movement in Chicago showed that 60 per cent was transferred through the city to connecting roads, more than half of it by trucks using the down-town business streets and less than half by trap-cars and freight tunnels. In Cincinnati, this trap-car freight is now being handled between various stations by motor cars with interchangeable bodies. This points clearly to the need of trucking by pass streets and detour routes, avoiding the central districts and yet giving the motor freight a chance to reach all parts of the city with reasonable speed. In Chicago, the first enterprise of this kind, known as the South Water Street Improvement, has been started. This will provide a wide double-deck detour thoroughfare around the Loop District, next to the river bank, with high-speed vehicles above and trucks below. In addition, it will provide a very large automobile storage capacity at the boundaries of the Loop District for all-day storage of business-men's cars, thus entirely avoiding the terminal congestion.

America has only one great long haul internal waterway, the Mississippi River and its tributaries, with its new canal connection with the Great Lakes. Such a waterway naturally constitutes a great intercepting trunk-line for through movement in large units between strategic rail-connecting points. It is difficult to understand how such a waterway system can ever become of the maximum utility without joint rates and through routes with the railroad system, due to the comparatively limited littoral that can be served by the waterways. In the interest of National efficiency, it would seem that all the people should have the advantage of water transport where they can use it to advantage. Under such circumstances, it is logic and justice that the economies of water transport that will develop automatically with increased traffic should be reflected back into the railroad system in some equitable manner through rates, so that both rail and water-haul may participate in these economies.

Outside the Mississippi System, the Warrior is the longest navigable river, not even excluding the Hudson. This means that the majority of the inland rivers will be confined to local, or comparative short-haul, tonnage which must stop at the seaboard until the intra-coastal canal system is developed as a water belt-line interconnecting all these river estuaries with one another and with all seaboard ports and cities. As this whole waterway system matures and tonnage develops, water transport may reveal unlooked-for economies, especially if it is linked up with railroad hauls where economic conditions warrant.

The total cost of developing and maintaining the inland waterways of the Country, excluding harbors and estuaries, since the beginning of the Nation's history is probably not more than one-half of what the Country spends in 1 year on public roads and will spend on railroads for the next year. The great problem of the collection and the distribution of rail freight rests largely on the highways. It costs the Country as much to haul freight to and from the railroad as to haul it on the rails and in the end the highways must transport the greater part. Motor competition with the railroad sinks into insignificance beside the larger problem of efficient terminal collection and delivery. The economic relation of long and short-haul costs, road versus rail, is rapidly being developed by the Connecticut road-tests and other studies and will soon be reasonably well known.

A better organization of the off-rail movement to and from the railroads will soon be needed to release the full line capacity of the latter and enable the terminals to operate in movement rather than storage. This will provide a quicker, turn-around, not only for cars, but also for ships and motors themselves. It will provide the much needed "vacuum pump" to clear the terminals more promptly.—From a paper presented by J. R. Bibbins before American Society of Civil Engineers.

STANDARDIZATION

STANDARDIZATION, per se, is not static; it is dynamic. It is the continuous process of crystallizing the best thought and practice of the industry or the art, and consciously eliminating that of proved lesser quality, utility, or value as unnecessary, wasteful and destructive. Standardization is the logical outgrowth of constructive effort, it is the measure of progress and the incentive for further advance. For no sooner has any one thing reached a certain degree of attainment or perfection than effort is concentrated in, and applied to, the problems of refining, improving and developing that thing to higher limits of performance, utility and satisfaction.

Standardization may begin at any point in the circle of commerce. In some cases efforts have been successfully directed at some specific features of the article, or phase of the process, under consideration without regard to the other existing variants. In other cases the primary effort has centered on the elimination of superfluous and unnecessary existing varieties in a common field of endeavor to the end that all such extraneous matters may be disposed of preparatory to intensive concentration of the varieties remaining. No matter which course is first chosen, the ultimate result is the same, for just as proved and demonstrable refinement causes the elimination of the unfit, so does such elimination induce improvement and advance in those that survive.

Managers everywhere are urgd to apply standardization as an effective means to eliminate waste. Products should be standardized consistently with the progressive development of manufacturing. Materials should be standardized to the fewest practicable kinds, sizes and grades. The details of equipment, including machine and tools, should be standardized so as to permit the widest interchangeability and the maximum usefulness consistent with improvements in design and invention.

Manufacturers may well be interested in the benefits of standardization, or "simplified practice," which term is more truly expressive of its purpose, for while manufacturers are primarily concerned with production, continuous operation of their plants rests on adequate distribution and steady consumption. Simplification, once started in any line, reaches into all three fields and with its progressive application brings numerous benefits that can be measured in dollars and cents.

Secretary Hoover has organized the division of simplified practice in the Department of Commerce to serve as a centralizing agency in bringing producers, distributors and users together and to support the recommendations of these interests when they shall mutually agree upon simplifications of benefit to all concerned. Nearly a hundred different trade associations are utilizing the services of the Division in carrying on their simplified practice program.

To date paving bricks have been reduced from 66 to 7 sizes. Wood beds and metal beds now have one common length with four standard widths for the former and two for the latter. The manufacturers of springs and mattresses favored this action, and now their products are being made in sizes to conform to the simplified line of beds. Metal lath varieties have been reduced from 80 to 12, and several other simplifications are in process of completion. These lines include lumber, bed blankets, milk bottles and caps, paint, oil and varnish, containers of all kinds, automobile parts and accessories, shipbuilding supplies, construction materials, contractors' equipment, oil-well supplies and equipment and many others.

Our material supplies should not be consumed in the fabrication of wasteful or slow-moving lines; neither should our relatively limited labor resources be applied to the production and the sale of such articles or commodities. Nor should our already congested transportation facilities be further clogged by the movement of such goods. We need to make a greater and more intelligent use of existing facilities and resources toward supplying the most common human wants. By so concentrating our effort, we can release a large amount of human thought and energy toward the development of new arts and sciences, social betterments and the improvement of standards generally.—R. M. Hudson in *American Industries*.

FRANCE'S FINANCIAL SITUATION

In less than three years after the armistice, France has been able through the activity and the perseverance at work of her population to re-establish her foreign trade and her economic situation.

While the effort was made, reconstruction of the devastated area was carried on without interruption. The following comparative statement of destruction suffered and reconstruction effected up to the end of 1922 will indicate to what extent the work has been completed:

Buildings destroyed or damaged,	741,993
Houses rebuilt or repaired,	553,977
Land devastated, hectares,	3,306,550
Reclaimed, hectares	3,018,000
Roads, railways, bridges, tunnels destroyed, km.,	68,237
Rebuilt and repaired, km.,	42,652
Canals, locks, bridges, destroyed or damaged,	2,349
Rebuilt and repaired, km.,	1,960

The cost of this reconstruction amounts to about 80 billions of francs, and in accordance with the terms of the Treaty of Versailles should have been borne by Germany. It is upon the failure of France to collect this sum that weigh down on the financial situation in France and will delay her complete recovery until a definite settlement is made; while to finish the reconstruction it will still be necessary to raise another 40 billions of francs.

It is necessary to emphasize, in making an analysis of the situation, the fact of the great power for saving of the French population. The saving power is estimated at some 30 billions of francs yearly; and such is the confidence of the people in overcoming the present difficulties that internal loans issued by the Government have always been absorbed readily. The total amount of these internal loans subscribed during the war and after the war stands at francs 99,791,000,000 for the consolidated debt, while the floating debt amounts to francs 101,000,000,000.

The economic situation of a country bears a direct influence on its financial situation. If the former is sound the latter, even though momentarily embarrassed, will gradually improve when every effort tends in that direction. This is the case of France; and the material progress made so far, under exceptional and trying conditions, should justify every confidence as to her ability in re-establishing her financial situation as she has rebuilt her economic situation.—Paul Duran, president French American Banking Corporation.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Sept. 10 and Oct. 10, 1923. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

AFFLECK, EDWARD T. (M) general manager, Dé Jon Electric Corporation, *Poughkeepsie, N. Y.*

BANES, WILLIAM K. (J) automobile electrician, Ditch Bowers & Taylor, Inc., *Baltimore, Md.*, (mail) 319 East 24th Street.

BLACKEBY, F. WALTER (A) manager of sales electric steel department, Eastern Steel Castings, Inc., Newark, N. J., (mail) 643 West 215th Street, *New York City.*

BRONSON, ADELBERT E. (A) secretary, Dill Mfg. Co., 7114 Carnegie Avenue, *Cleveland.*

CHASE & Co., L. C. (Aff) 89 Franklin Street, *Boston.*
Representatives:
Hopewell, Frederick C., partner.
Hopewell, Henry C., partner.

CHERRY, GEORGE H. (A) sales engineer, American Bosch Magneto Corporation, 5810 Woodward Avenue, *Detroit.*

CISLER, WALKER L. (J) cadet engineer, Public Service Electric Co., *Newark, N. J.*, (mail) 45 Thomas Street.

COBB, FRANCIS S (A) president and treasurer, Seamans & Cobb Co., 140 Essex Street, *Boston.*

COSHOF, M. E. (E S) student, Tri-State College of Engineering, *Angola, Ind.*, (mail) P. O. Box 253.

DAVIS, JACK B. (A) production manager, Standard Textile Products Co., *Buchanan, N. Y.*

DETTLINGER, F. W. (J) laboratory engineer, Plant 5, Studebaker Corporation, *Detroit*, (mail) 705 Y. M. C. A. Building.

EDINGER, EDWARD PETER (J) student engineer, Franklin Auto Co., *Syracuse, N. Y.*, (mail) 500 Rowland Street.

GRABFIELD, JOHN J. (E S) student, Massachusetts Institute of Technology, Cambridge, Mass., (mail) 1933 Commonwealth Avenue, *Boston.*

HALL, H. R. (A) assistant to general service manager, New York Yellow Cab Sales Co., Inc., *New York City*, (mail) 604 West 140th Street.

HOMAN, A. E. (A) general manager, C. G. Spring Co., 1825 East 13th Street, *Cleveland.*

KNIGHT, BOYCE W. (A) sales manager, Ensign Carburetor Co., Los Angeles, (mail) 3108 South Michigan Avenue, *Chicago.*

LAKE, HARRY W. (A) inspector of aeronautical engines, engineering division, Air Service, McCook Field, Dayton, Ohio, (mail) care of Curtiss Aeroplane & Motor Co., 74 Kail Street, *Buffalo, N. Y.*

LEMON, BURTON J. (M) technical service department, United States Tire Co., 1790 Broadway, *New York City.*

MILLER, WALTER (M) manufacturing manager, Marland Refining Co., *Ponca City, Okla.*

MULLER, JOSEPH J. (M) designing engineer, Belmont Motors Corporation, *Lewistown, Pa.*

NEWTON, F. I. (A) secretary, G. & O. Mfg. Co., 598 State Street, *New Haven, Conn.*

OTTENHOFF, W. B. (A) manager of engineering service division, Indian Refining Co., Inc., 244 Madison Avenue, *New York City.*

PANEK, EMIL (A) engineer, Globe Machine & Stamping Co., *Cleveland*, (mail) 9608 Baltic Road.

PARKER, ARNOLD GEORGE (A) designing draftsman, Manly & Veal, New York City, (mail) 3737 45th Street, *Corona, N. Y.*

PETERSON, EYVIND (A) die-casting engineer, Fairbanks, Morse & Co., *Beloit, Wis.*, (mail) 1418 Hull Avenue.

ROBINSON, RICHARD HERBERT (E S) student, Tri-State College, *Angola, Ind.*, (mail) P. O. Box 204.

SCHROEDER, A. F. (A) chief inspector, Falls Motors Corporation, *Sheboygan Falls, Wis.*

SHERMAN, E. A. (A) district manager, Westinghouse Air Spring Co., Bridge Plaza, *Long Island City, N. Y.*

SHERWOOD, H. H. (A) president, Sherwood Petroleum Co., Inc., Building 1, Bush Terminal, *Brooklyn, N. Y.*

VANATTA, JEAN K. (M) mechanical engineer, Mudge & Co., 4425 West 16th Street, *Chicago.*

WARNER, JOHN A. C. (M) assistant research manager, Society of Automotive Engineers, Inc., *New York City*, (mail) 625 West 169th Street.

WEBSTER, H. G. (M) consulting engineer, 1427 Monadnock Building, *Chicago.*

WISCONSIN STEEL Co. (Aff) 606 South Michigan Avenue, *Chicago.*
Representative:
Courtright, B. F., metallurgist.

Applicants *for* Membership

The applications for membership received between Sept. 1st and 15th, are given below. The members of the Society are urged to send any pertinent information they may have in regard to these applicants to the Council. Such information should have the consideration of the Council before election. It is requested that such communications be sent promptly.

[illegible] School, Inc., [illegible]

[illegible] H. P. [illegible] Mfg. Co., *Battle Creek, Mich.*

[illegible] Wilcox Rotary [illegible] engineer, [illegible]

BECK, GEORGE E., student, Columbia University, *New York City.*

[illegible] Self Feeding Vaporizer Corporation, *New York City.*

[illegible] supervisor of time study, Chandler Motor Car Co., [illegible]

[illegible] Timken-Detroit Axle Co., *Detroit.*

[illegible] A. [illegible] and general manager, Bryan [illegible] Co., *Bryan, Ind.*

[illegible] WILLIAM BISSET, automobile engineer, Cameron Garage, [illegible]

[illegible] Motor Transit Co., *Los Angeles, Cal.*

[illegible] D. [illegible] White, *Detroit.*

[illegible] Yellow Cab Co., *Philadelphia.*

[illegible] WILLIAM D., draftsman, Philadelphia Motor Coach Co., [illegible]

[illegible] S. K. F. Industries, [illegible]

[illegible] Budd Corporation, *Detroit.*

[illegible] Vesta Battery Corporation, *New York City.*

[illegible] A. [illegible] engineer, International Motors Co., *New York City.*

HANSEN, H. A., manager, Stromberg Motor Devices Co., *Detroit.*

HANSEN, C. P., engineer, Brewster & Co., *Long Island City, N. Y.*

[illegible] Steel Co., *Chicago.*

JOHNSON, FORREST L., student, The State College, *Annola, Ind.*

KNOWLTON, ASA WALTER, student engineer, Remy Electric Co., *Anderson, Ind.*

KOLESKY, B. V. KAVAN, designing engineer, Aeromarine Plane & Motor Co., *Keyport, N. J.*

LLOYD, ARTHUR G., [illegible], Wright Aeronautical Corporation, *Paterson, N. J.*

MCCALMONT, A. W., vice-president and chief engineer, Briscoe Detroit Corporation, *Pontiac, Mich.*

MCEWING, JAMES P., designing engineer, Sawyer-Massey Co., *Hamilton, Ont., Canada.*

MCKEON, WILLIAM C., assistant chief draftsman, Walden-Worcester, Inc., *Worcester, Mass.*

NATIONAL AUTOMOBILE UNDERWRITERS CONFERENCE, *New York City.*

NOELKE, G. HAROLD, superintendent, Huck Axle Corporation, *Chicago.*

PETCHVALL, J. J., superintendent of transportation, New York division, Gulf Refining Co., *New York City.*

PIONEER, DANIEL A., mechanical engineer, Hyatt Bearings Division, General Motors Corporation, *Harrison, N. J.*

REAGAN, NEAL FRANCIS, assistant general service-manager, Yellow Cab Co., Sales Agency, *New York City.*

SEWALL, STANLEY P., advertising manager, White Co., *Cleveland.*

SHEFF, A. T., mechanical superintendent and designing engineer, California Transit Co., *Oakland, Cal.*

SCHEE, ALBERT J., instructor in mechanical engineering, Stevens Institute of Technology, *Hoboken, N. J.*

STAHL, R. E., works manager, Bryan Harvester Co., Inc., *Peru, Ind.*

SMITH, FRED C., National director Y. M. C. A. automotive schools, United Y. M. C. A. Schools, *New York City.*

WEST, FRED A., sales engineer, Aluminum Co. of America, *Detroit.*

THE

JOURNAL
OF THE SOCIETY OF
AUTOMOTIVE ENGINEERS

Published by the SOCIETY OF AUTOMOTIVE ENGINEERS, INC., *29 W. 39th St., New York*

Issued monthly, $1 a number, $10 a year; foreign $12 a year; to members, 50 cents a number, $5 a year. Entered as second-class matter, Aug. 23, 1917, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Aug. 2, 1918.

H. W. ALDEN, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

Vol. XIII December, 1923 No. 6

INDEX

Applicants for Membership		533
Applicants Qualified		534
Application of the Diesel Engine to the Yachting Field—George A Colley		450
Causes of Accidental Deaths		492
Census of Vehicle Industry		460
Chronicle and Comment		443
Decelerometer for Testing Automobile Brakes—William S James		499
Discussion of Papers at the 1923 Production Meeting		473
Irrigation Development		472
Marketing of Agricultural Products		449
Meetings of the Society		511
Motor-Vehicle Wheel-Alignment—John F Duby		453
Nature of Matter—H B Lemon		466
Notes and Reviews	Adv Section	10
Observations on the Automotive and Highway Fields in Europe		493
One-Crop Farmer		472
Packard Single-Eight—J G Vincent assisted by W R Griswold—(Appendices and Discussion)		485
Personal Notes of the Members	Adv Section	2
Photoelastic Method Applied to Rigid-Airship Research—Thomas H Frost		497
Price of Agricultural Products		460
Price of Wheat		498
Public's and the Car-Builders' Attitude Toward Balloon Tires—J E Hale		461
Research an Important Factor in Highway Improvement		495
Spring-Movement and Vibration Study of Cars in Action—T J Litle, Jr		445
Tentative Standardization Work		502

NEW YORK SHOW

We shall exhibit a complete line of crankshaft forgings at the New York Automobile Show.

Of particular interest will be our display of sections of forgings showing internal structure and flow of metal.

WYMAN-GORDON

"The Crankshaft Makers"

SPACES 335-336-337—THE ARMORY

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIII December, 1923 No. 6

Chronicle and Comment

Discussion of Factory Problems

THIS issue of THE JOURNAL contains the corrected report of the discussion that followed the several papers read at the Production Meeting in Cleveland on Oct. 25 and 26. Frequently it is found that the discussion of a paper adds materially to its value, bringing out points not covered by the author; this is true of many of the Cleveland meeting papers. The discussion will prove interesting reading as an important supplement to the papers that appeared in the November issue of THE JOURNAL. All the Production Meeting discussion is grouped together, starting on p. 473.

Annual Dinner in New York

ALTHOUGH the Annual Meeting of the Society has been moved to Detroit for 1924, that great institution of the automotive industry, the Society's Annual Dinner, will be held in New York City as in years past. Attracting upward of 1000 men, this function can truthfully be called the largest formal gathering of automotive men held during the year. It will be held at the Astor Hotel on Thursday evening, Jan. 10. E. S. Jordan has agreed to take the helm as toastmaster on this occasion. Men prominent in public life will give inspiring talks and the usual atmosphere of good-fellowship will prevail. Application blanks to be used in ordering Dinner tickets will reach the members with the next issue of the *Meetings Bulletin* about Dec. 15.

New Detroit Section Office

AFTER Dec. 1, the office of the Detroit Section will be located in the General Motors Building, where it will be more accessible to the members and in a position to render increased service. Members living in the Detroit area are invited to call and inspect the new quarters. A file of the publications of the Society is available for reference purposes, and the Assistant Secretary who is in charge will be pleased to supply information on any of the Society services or activities. Men seeking positions will find bulletins of the national employment service of the New York City office on file there and assistance will be given in finding local employment as well. Car and parts companies in the Detroit district will find the national employment service an efficient means of securing experienced personnel. The New York City office maintains an intimate contact with the Detroit office and many matters pertaining to national activities can be handled efficiently through the local Assistant Secretary in the General Motors Building.

A Meeting for Motorboat Engineers

ON the morning of Jan. 9, the Society will hold its annual Motorboat Meeting and Luncheon at the Hotel Commodore, New York City. This meeting is arranged to enable engineers interested in the design of motorboats and marine engines to discuss the major engineering problems in their field. It also offers them an opportunity to become better acquainted with one another and to exchange experience for the general benefit of the motorboat industry. This date occurs during the week of the national Motorboat Show in New York City. It is planned to have two papers and a round-table discussion in the meeting, which will start at 10:30 a. m. The luncheon will follow at 1 o'clock and will be concluded with a brief talk by one of the Country's foremost motorboat enthusiasts.

American Petroleum Institute Meeting

OUR members have been invited by the American Petroleum Institute to attend the meetings that will be a part of its convention in St. Louis, Dec. 11 to 13. Several papers will be read at these meetings on different phases of the automotive-fuel problem. Some of these will be given by members of the Society who will represent it on the program. Results of the fuel-volatility research conducted at the Bureau of Standards under the direction of the Research Committee of the Society will be presented. This work is being financed jointly by the American Petroleum Institute and the National Automobile Chamber of Commerce. Automotive lubricants also will receive consideration in these meetings. See p. 516 of this issue for the divisions of the program that are of particular interest to automotive engineers.

The Dayton Service Meeting

A REPORT of the Service Meeting held at Dayton on Nov. 20 and 21 is printed in this issue of THE JOURNAL, starting on p. 523. This meeting was held under the joint auspices of the Society and the National Automobile Chamber of Commerce for the purpose of

Annual Meeting in Detroit

IN all probability the 1924 Annual Meeting will be attended by more members than any previous national gathering of the Society. This seems likely because the meeting will be held in Detroit near the geographical center of the industry and will not conflict with the numerous meetings, luncheons, social functions and show duties that have demanded so much of a member's time during the New York Show week. Professional sessions will run for 4 days from Jan. 22 to 25. Papers are being selected for their informative value and will be of a high standard. Topics of current interest will be the only ones discussed. There will be something for the designer, the research engineer, the production man and the service executive. All the latest models of passenger cars will be on display at the Detroit Automobile Show during the week of the meeting. Reduced railroad-fares from all important automotive centers will minimize the expense of attendance. Complete announcement of the arrangements made to date appears on p. 530 of this issue.

Discussion of Sections' Methods

AT the last meeing of the Council, the following were named as members of a special committee to study and improve so far as possible the methods of procedure of the Sections: B. B. Bachman, *chairman;* J. H. Hunt, T. J. Litle, Jr., H. W. Slauson and John Younger. Considerable correspondence has been conducted recently by the Sections Committee and this special committee for the purpose of securing comments from those members who are specially qualified by experience to discuss Sections affairs.

There is much sentiment in favor of reestablishing the Section Associate, but not all of the Sections favor such enrollment of non-members of the Society as affiliates of the Sections. There is also a difference of opinion among those who have expressed views on the matter of increasing the annual dues of Society members by an amount to include the payment of Sections dues by those who reside in the respective Section territories. Several of the Sections or their Governing Committees favor amending the Constitution of the Society to this effect. There seems to be very little dissension from the feeling that in any event the dues of all the Sections should be collected through the office of the Society, concurrently with the annual dues of the parent organization.

Valuable Gear-Production Experience

MEMBERS who may be investigating means of manufacturing silent running transmission gears will find many interesting statements in the account of the Nov. 15 meeting of the Detroit Section which is printed on p. 514 of this issue of THE JOURNAL. This meeting brought out one of the most productive discussions of the gear-noise problem that has been held by the Society.

This meeting was the first of a series of monthly meetings of the Detroit Section that will be devoted especially to manufacturing problems and production methods. Over 200 men were in attendance, showing that the new step is appreciated by the factory executives. The Section will continue its usual monthly meetings devoted to design and research matters, these being held on the first Thursday of each month and the production meetings on the third Thursday.

Head-Lamp Illumination

MEMBERS of the Sections of the Society are making specific plans to cooperate locally with automobile clubs, dealers, car-owners' associations and municipal authorities with a view to improving head-lamp illumination conditions as much as possible, as soon as possible. The Metropolitan Section has designated J. W. Lord as the chairman of its committee. The Detroit Police Department maintains an adjusting station where an owner can have his car's head-lamps inspected as frequently as he desires. The Detroit Section reports that the main difficulty is to secure the interest of the car-owners in this matter. It is clear that a general effort should be made to keep the subject before the public. Incidentally, a Detroit ordinance requires that there be sufficient light to discern an object 100 ft. ahead of a car. In Massachusetts, the Registry Department designates head-lamp focusing stations, a card being given to the driver certifying that his equipment has been inspected. Secretary V. A Nielsen, of the New England Section, is of the opinion that the assistance of citizens must be enlisted in an effort to remedy the bad conditions. There are obvious limitations on what can be done soon at the best. The full cooperation of all members of the Society locally is sought and they are requested to write the office of the Society expressing their views as to what means would be most effective.

What About Highways?

ARE the design and construction of highways keeping pace with the increased demands? However this question may be answered, it is certain that efforts are being made to bring the matter to a favorable issue.

An account of the recent session of the Advisory Board on Highway Research of the National Research Council will be found in this number of THE JOURNAL. From the discussion that took place at this session, it was obvious that the numerous cooperating organizations are making valuable contributions toward the betterment of present conditions and toward the solution of problems that have a bearing upon future requirements.

One of the most important of the highway researches now in progress in which the Society is cooperating is that sponsored by the Bureau of Public Roads; the plans were briefly outlined in the September issue of THE JOURNAL. This project, it is hoped, will bring forth new material relating to the effect of the vehicle on the road and vice versa. Furthermore, it is probable that the tests will reveal interesting facts concerning the destructive effect of the road upon itself as determined by the degree of smoothness of its surface. This is undoubtedly a much greater factor than has been recognized heretofore.

At the Nov. 9 meeting of the cooperative committee interested in this research, a report showing progress in preliminary work was presented. A steering committee of three was appointed to assist in deciding technical questions without necessitating the assembling of the entire committee. Dr. H. C. Dickinson, research manager of the Society, was chosen to act on this committee.

Spring-Movement and Vibration Study of Cars in Action

By T. J. Litle, Jr.[1]

Indiana Section Paper *Illustrated with* Drawings and Charts

PREVIOUS efforts to obtain comfortable riding-qualities for passenger-carrying automobiles are mentioned, and a device that combines a recording seismograph and a spring-action recorder is illustrated and described, since such a device is essential in conducting investigations of this character.

Methods governing the use of the device when studying spring action and chassis vibration are outlined, and the results obtained are presented graphically and discussed. Several unique features characterize these tests and are worthy of consideration, not only because of the results obtained thereby but as being good illustrations of what can be accomplished by substituting unusual and perhaps spectacular methods in special instances for ordinary practice that has failed to produce some desired result.

IN designing for comfortable riding in motor vehicles many difficult problems are met that have been with us many years and I believe are only partly solved. I will not refer to historical installations and drag you through the long development from the ox-cart to the automobile, but will simply refer to modern installations and the means that I have employed for determining and selecting the proper equipment.

The early automobiles traveled more slowly and the problem was not then so difficult; but now, with greatly increased speed and the more exacting demands of an educated public, we are compelled to pay greater attention to riding comfort. In addition, we have increased the touring range of our cars very much. It is common at present to hear of owners who travel 400 miles or more in a single day, with the larger cars; and they demand that they should be able to accomplish this without being temporarily crippled. The difficulty was that, when the more powerful engines were installed in cars to give them higher touring-speed, many builders resorted to the practice of using very much stiffer springs. This unquestionably made the cars harder-riding. Then came a period when the tops were given more headroom to increase the safety factor; to prevent the passenger from having his brains dashed out on the bows immediately above the seats.

The next logical step was the development of devices to restrain the violent rebound and excessive spring-action. Some of these devices were effective, but, at the same time, by simply retarding the spring action, had the effect of stiffening the springs, approaching nearer the goal that some engineers seemed to be aiming for, namely, to give the automobile all the riding advantages of a truck. In work of this character, which naturally is done in the experimental department and directed by the officials and by the entire engineering department, great differences of opinion exist. While in charge of such a department, I made up my mind that the old cut-and-try methods and the vague reports made concerning certain road-tests were perfectly foolish. Usually, a man forgets an impression received from this kind of a test, or becomes easily confused after going through several tests and then hopelessly muddled. All this goes to show that some kind of a measuring instrument and recording device is essential in such an investigation.

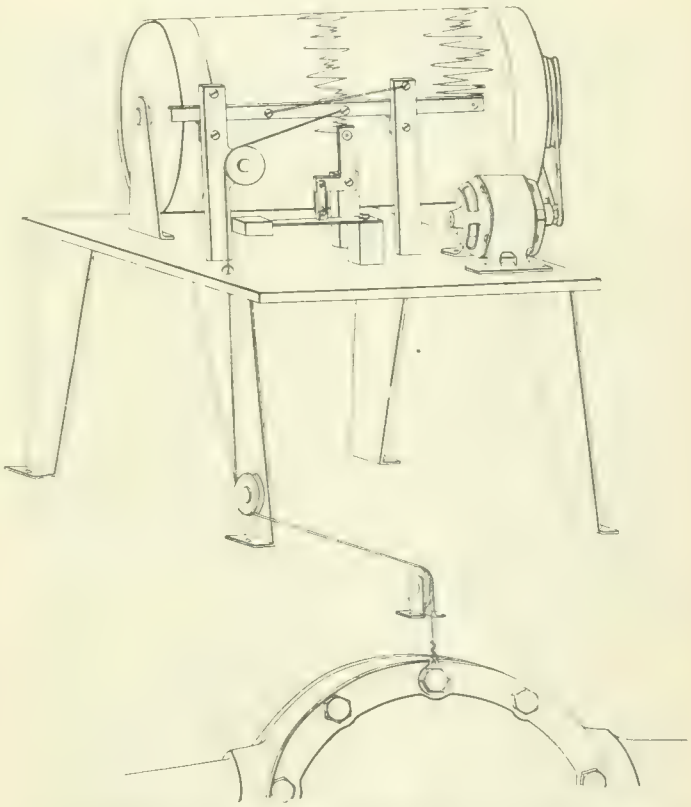


Fig. 1 Sketch of Recording Seismograph and Spring-Travel Deflector

Measuring and Recording Devices

After considerable preliminary work a device was constructed that combined a recording seismograph and a spring-action recorder; it is illustrated in Fig. 1. With this device the attachment is made with the axle by a cord running over pulleys to the instrument that rests upon the car floor. A reciprocating motion is imparted to a light sliding member that carries a stylus which makes a record on a moving strip of paper. The parts are all made extremely light. A thin braided-silk fishing-line was used, and the sliding member was made of a thin strip of spruce. Combined with a recording instrument, and making its record on the same sheet, was a seismograph consisting of a small weight attached to a thin leaf-spring that also was provided with a stylus. Typical

[1] M.S.A.E.—Chief engineer, Lincoln division, Ford Motor Co., Dearborn, Mich.

records are reproduced in Figs. 2 and 3. The "inches" noted at the left of the upper graph in each case indicate the extent of the spring deflection both above and below the normal resting position; that is, the actual relative motion between the axle and the chassis. The lower graph on each chart is the seismograph record that is made simultaneously with the spring-deflection record. The scale to inches at the left indicates the extent of movement of the weight at the end of the seismograph spring and roughly indicates the deviation in the body travel from a horizontal line.

Testing Methods

After the instrument had been placed in a car, a road was selected for testing purposes and subsequent tests consisted of driving the car repeatedly over the same course at the same speed. On the first trip, in a series of tests, a little discharging powdered lime was arranged to trace on the left rear-wheel so that the car could be guided over the same course in subsequent trips. During the course of the trip, an observer was employed to make notes continuously, directly on the recording strip. These notes consisted of recording any comments of the passengers as well as the condition of the road and, if the car speed was changed purposely during the test, a mark was made to indicate the point of the change. When the car bumped its axle, as was occasionally the case in a bad hole, this was noted and later led to a change in the form of the axle bumper.

The device I have described is not a precision instrument in any sense of the word, but it proved extremely valuable to the experimental department. I found the device very useful in studying the action of car springs, shock-absorbing devices, large-section tires and body mounting on chassis.

Study of Springs

In the study of springs, I determined that the use of a bundle consisting of a large number of thin leaves with tapered ends actually gave better results than a spring built-up with a smaller number of thick leaves with the ends dubbed off square. In one high-priced car, I settled upon the use of a front spring containing 14 leaves for regular production. The theory governing the use of a large number of spring leaves is that:

(1) Such a composite spring, built up of a number of thin spring-leaves each having a different period, will be in itself dead-beat. In my opinion the car springs should contain as many thin leaves as it is practicable to use

(2) In addition to this period interference, we have the increased inter-leaf friction; and this is extremely desirable

(3) Better insulation against shock is provided; for, the more joints and the more oil-films in the shock-conducting path, the more efficient they will be as shock insulators

Another use for the recording device was in the design of the rubber bumper on the axle. When simply a square or cylindrical block of rubber was used, a rebounding thud upon the body struck the bumper was very pronounced because the resistance in the bumper was built-up too rapidly, as noted on the graph that was taken during the test. Later, the form of this bumper was changed to one having a pointed section. In this form, the pressure at the time of impact, which resulted in a softer bump to the body, built-up more gradually than in a square bumper

Shock-Absorbing Devices

The device is particularly valuable in the study of shock-absorbing devices, for such devices must be employed to prevent excessive rebounding. Many of the simple friction devices in use today unquestionably affect the rebound in the car but they have a great tendency to stiffen-up the ride. In some cases, they give very much the same effect as would be obtained if heavier springs were used.

Several of the hydraulic types of shock-absorber were studied also, and it was during this investigation that an important development occurred. It had been repeatedly observed that a dashpot used to restrain the rebound of the spring, in much the same manner that a dashpot is used on a door to prevent it from slamming, was very effective, particularly to enable the car to be driven rapidly over a rough road. But with all of these devices, it was noticed also that soft riding qualities over the city streets and the good concrete roads had been sacrificed. We decided that what was needed was a selective shock-absorber that would be cut-out of action automatically on the comparatively smooth roads and city streets but be brought into use on the rough roads. This would allow the use of the softest and most flexible springs. Such instruments were then designed. Subsequent tests proved that the conclusions drawn from the readings of the recording instrument, as shown in Figs. 2 and 3, were correct and the car equipped accordingly in production, in combination with the use of the car springs containing a bundle of many thin leaves, is remarkably easy-riding.

Study of Tires

The next important research made with the instrument was in connection with the study of large-section, low-air-pressure tires. This most interesting development promises to be of great commercial value. In this case, the primary record on the graph, the one indicating the relative action between the axle and the body, was very much diminished; that is, the unsprung mass made up of the axle, wheels and the like, had very much less reciprocation, the consequent steadying action on the passenger load being indicated by the recording seismograph. This is accounted for by the fact that the low-air-pressure, large-section tire does not bound over and is not elevated by the ordinary inequalities of the road surface, for it is a fact that small stones and ridges in the road actually imbed themselves in the softer tire. When considered purely from the standpoint of easy riding, these tires are a great success. Some problems remain to be solved in connection with their use on passenger cars. One of them is the increased steering effort required; I believe that will be solved in the near future by those who are specializing on steering-gear development.

In the use of these large tires considerably more bounding action in the front suspension occurred; and it was absolutely necessary to apply shock-absorbers. Some attempts were made to support the instrument on the seat cushions by strapping it in position, but this attempt to simulate the passenger and exactly record his riding sensations was not altogether successful because a passenger relaxes more or less while riding and the instrument of course does not have that faculty. I believe, however, that the instrument must be adapted eventually to record the riding qualities from the seat cushion, because cushion springs perform an extremely important function in producing easy riding. When the rebound

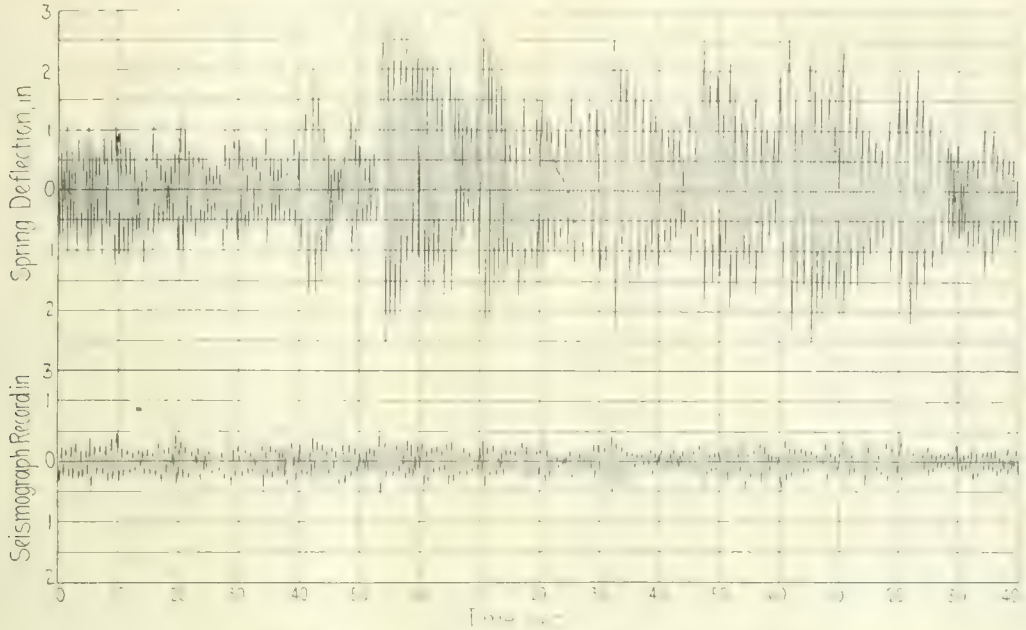


FIG. 2—VIBRATION CHART WITHOUT SHOCK-ABSORBERS

can be diminished greatly by efficient shock-absorbing devices, very much softer cushion-springs can be employed. I have thought many times that a cushion spring should unquestionably be built or provided with some rebounding dampener, but I know of nothing of the kind that has been suggested that is not either extremely foolish or unnecessarily trappy.

ENGINE VIBRATION

Engine vibration and its consequent effect on the chassis and body cannot be studied so well with this instrument. I have found a vibration tachometer to be extremely useful in this connection. It is of the type containing a series of vertically disposed spring leaves supported at the lower end and provided with small weights at the upper end, and is very effective. By simple calibration, the periods of each reed can be determined and, later, when the engine is running and one of the reeds is seen to break into vibration, a clue is thus given to the offending member in the engine that sets-up the vibration. During the early development of one powerplant an extremely annoying vibration was encountered and the tachometer reading led observers to suspect an out-of-balance condition due to too great reciprocating weights in the pistons and the rods. The management was extremely skeptical in this case, particularly as to the accuracy of such an apparently simple instrument. I attended one conference at which it was proposed to investigate the subject experimentally in various alternative ways.

(1) It was suggested that the vibration might be torsional vibration in the crankshaft, and a heavier crankshaft was to be constructed

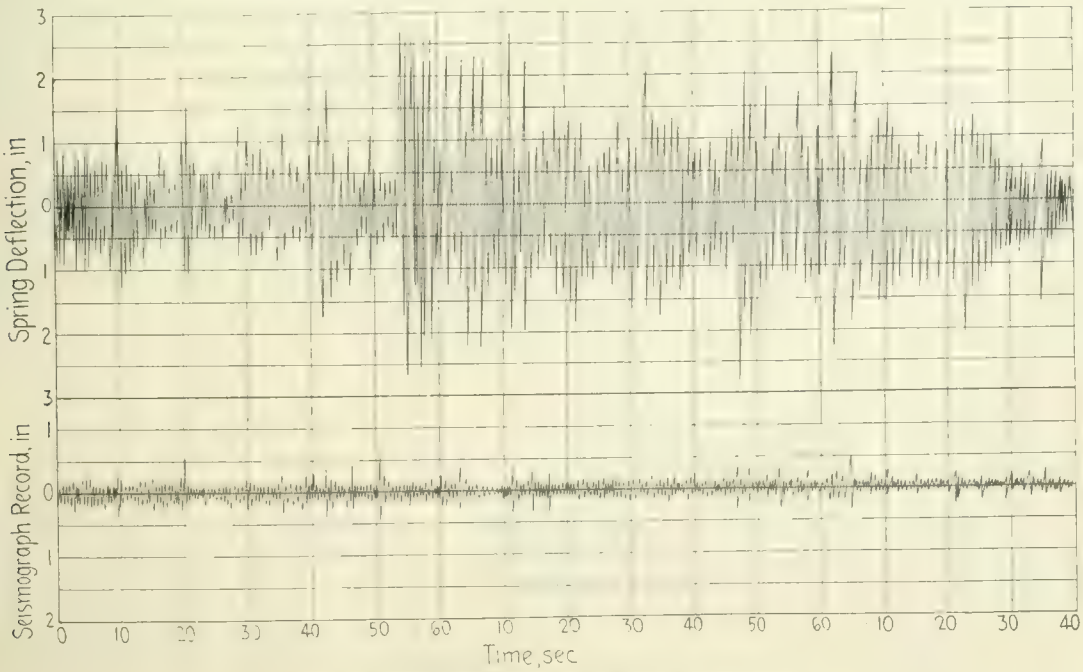


FIG. 3—VIBRATION CHART WITH SHOCK-ABSORBERS

(3) A vibration dashpot was to be installed on the front end of the crankshaft

(4) A long vertical shaft driving a distributor at the top and an oil-pump at the bottom was suspected of being too slender, and a larger and stiffer one was to be constructed

(5) The fan might be out-of-balance and was to be investigated

(6) The front end of the silent-chain might itself get into vibration at certain periods

(7) The accessory shaft on the side of the engine that drives the water-pump and the generator, running at approximately 1½ times the engine speed, was strongly suspected. This was to be ground-down and a larger and perfectly balanced unit substituted

(8) The pistons were thought to be too heavy. At that time they were made of cast-iron and were extremely heavy. These were to be replaced by aluminum pistons, although this kind of a change met great antagonism from the older engineers

(9) The connecting-rods might be too heavy, but any lightening of them was opposed strongly

(10) A number of other minor details were enumerated

Vibration Tests

To have determined experimentally just where the trouble lay by carrying out all the suggestions made at the conference would have consumed at least several weeks, and a quick decision was imperative. I had a very different plan. The next morning I had a closed car towed behind a test chassis and, riding in the rear car and letting in the clutch in high gear with the ignition cut-off, I noted that the vibration occurred at exactly the same periods and the same car-speeds as those at which it occurred when the engine was running under own power. I then disconnected one moving part after another from the engine until nothing was left in motion except the crankshaft, rods and pistons; but the vibration still existed, even after relieving the compression by completely removing the cylinder heads. This indicated clearly that the vibration was due to excessive reciprocating weight.

Weight was gradually removed uniformly from each piston until the vibration became negligible; the weight then had approximately 50 per cent of the former weight. It was known, of course, that aluminum pistons could be obtained that were well within this range. When aluminum pistons were substituted and the car was run by its own power, a very smooth running job was obtained.

The problem remains in connection with the construction of the first closed bodies in production, it was found that a very annoying and almost deafening drumming vibration occurred at certain distinct periods. This car was built with a metal roof that was indeed a work of art and was greatly cherished by the body designer. But, notwithstanding the fact that this great diaphragm member of the body was so strongly suspected by many of the engineering staff, the management felt very uncertain about the diagnosis. I remembered a very interesting experiment at college during the first year of the physics course, in the study of sound phenomena. That was the one graphically representing the vibration on a plate by sprinkling sand upon the surface and vibrating the plate by drawing a violin bow over its edge. The plate being thus set into vibration, a distinct design was produced by a rearrangement of the sand particles, the nodes and anti-nodes appearing in great contrast. Recalling this, I sprinkled sand all over the metal top on this closed car and, at certain engine speeds, a design was shown in a most striking manner at three points on the top, as reproduced in Fig. 4. The management was thus shown that we had a most efficient and sympathetic diaphragm on the top of this body which made the whole structure a wonderful resonator. It was suggested that the top be replaced immediately with a top of soft construction. However, this suggestion was not carried out immediately, as the management wished to know whether it would not be possible to dampen out the vibration at the anti-nodes. I built some experimental equipment consisting of a series of weights placed on the underside of the metal top at these points, by cut-and-try methods. The vibration was not absorbed until 55 lb. of weight had been applied to the top. To apply so much weight to a thin top would be absurd, of course. These weights, furthermore, had to be very rigidly attached; otherwise they themselves would set-up an additional rumble by impact. The foolish scheme of the hard-top construction was abandoned.

Still another interesting method of detecting vibration consists of placing a beaker of gasoline at various points along the top flange of the side-bar. Gasoline and not water must be employed for this purpose. When placed above the anti-nodes on the bar, the surface of the gasoline will break into violent vibration. In some cases the liquid will become so agitated that drops actually will jump out of the top of the beaker, as shown in Fig. 5. These locations on the bar can then be charted; they indicate clearly points at which the body bolts should not be attached. The body bolts must be located at the nodes or the parts of the bar that are in repose.

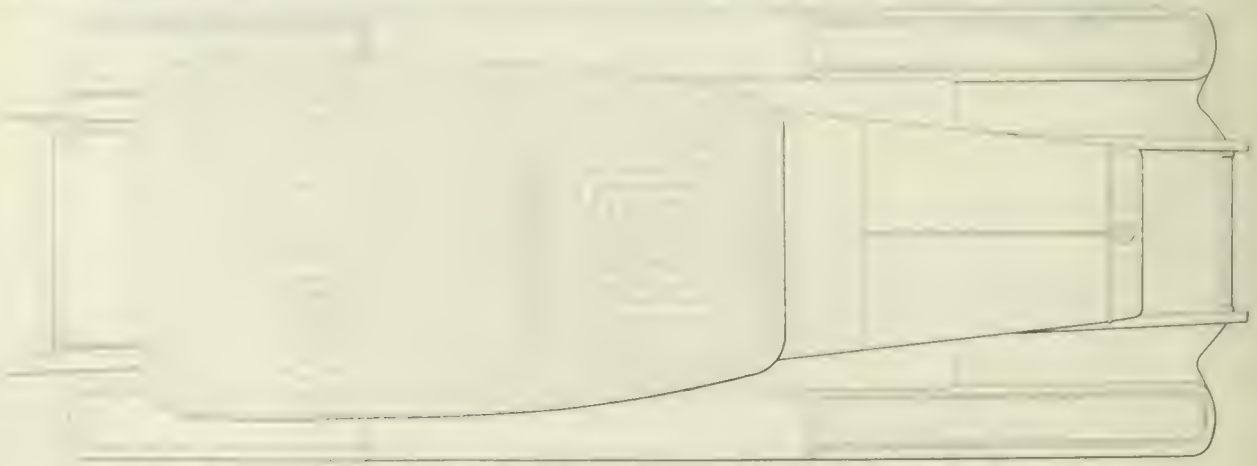


Fig. 4—The Form of the Sand Particles Due to Vibration

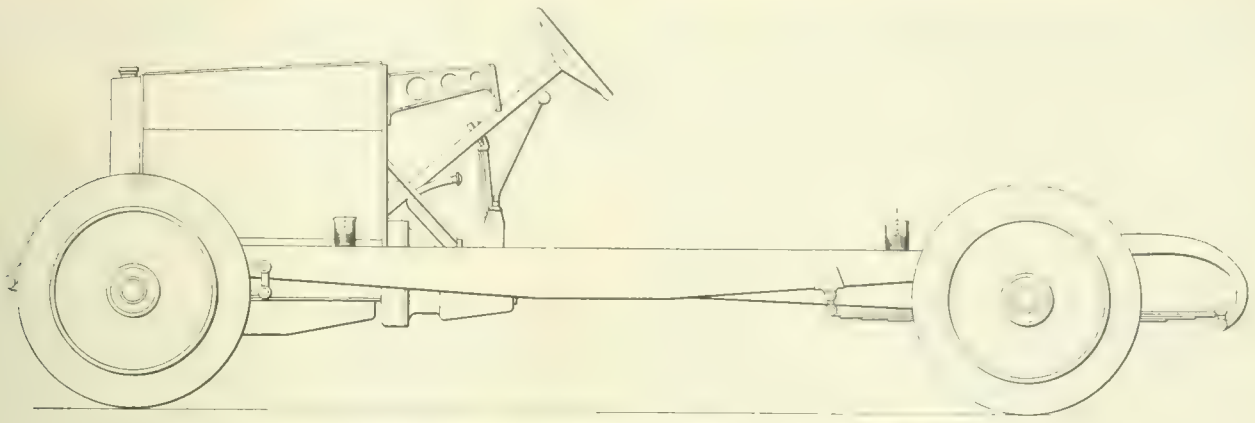


FIG. 5—SIDE VIEW OF THE CHASSIS SHOWING BEAKERS OF GASOLINE PLACED AT ANTI-NODES ON THE SIDE BAR

I mention these things merely to show that the engineer sometimes must be resourceful in selling his conclusions to the management. I believe that you engineers have many problems of like nature and that frequently you do not use enough common-sense in their solution. I am a great believer in "hob-nobbing" with the practical men in the shop, and have obtained many valuable ideas from them; but the men have to be "drawn-out," and considerable tact is required in doing this. I know that many engineers will disagree with me as to the way I approached the problem of the engine having excessive vibration, but I believe that spectacular, convincing methods are absolutely necessary at times to accomplish one's purpose.

MARKETING OF AGRICULTURAL PRODUCTS

I AM skeptical as to the possibilities of very great gains to the growers of wheat and cotton from the efforts to make a wholesale substitution of new cooperative marketing organizations for the existing machinery of the grain and cotton trades. An immense volume of capital is already employed in the existing machinery and to duplicate it would cost a vast amount. Whether agriculture can afford to build up elaborate and expensive machinery to do work that is already reasonably well done is a grave question. Another grave question is whether newcomers in the field could possibly duplicate the accumulated knowledge and experience of the men now in the trade except as they take over experts now employed in the trade.

In general, it would be well for those contemplating cooperative organization to study closely the existing machinery of the trade, and see how far it is necessary to duplicate it. In some cases, a cooperative might function for very limited purposes, taking care merely of certain local problems, and get much better service from reputable, established trade organizations for the rest of its business than it could possibly get through an amateur organization of its own. In other cases, the existing trade machinery may be so unsatisfactory that it is necessary to replace it entirely. But trade relations, trade knowledge, expert experience, personal contacts, good-will, long standing relations with businesses and organizations in foreign countries, all these things take time, money and thought to build. They should not be lightly thrown away. They should not be recklessly duplicated. It is better to use the existing machinery as far as possible.

One of the merits of the present tendency in cooperative marketing is that it has divorced itself largely from fraternal and political purposes and that it offers itself to the farmer as a business proposition, to study it in each case on its merits as a business proposition and not to allow himself to be stampeded by revival enthusiasm or political excitement into accepting it, unless a careful analysis of cold figures shows that it really will pay better than some slighter modification of existing practices.

The worst possible thing that could happen to the wheat industry is that organization of a holding pool of such financial power that it could successfully carry 200,000,000 bu. through the current crop year and into another crop year, with a concomitant increase in the price for wheat during the coming year. Production of wheat throughout the world would be enormously increased and the markets would be utterly swamped in the following year. A more probable result of such an attempt would be a temporary increase in price and holding back of American wheat from the world's markets, while Canada, Argentina and Australia marketed their supply, and then a collapse, before the year was over, in the holding movement, with greatly demoralized prices of American wheat that had lost its export market. The movement might last long enough to lead to increased planting of winter wheat during the coming autumn. It is characteristic of a policy of this sort that its temporary success necessarily involves a long-run disaster, since unorganized producers are greatly influenced by price in the volume of their planting and output.—B. M. Anderson, Jr., Chase National Bank.

The Application of the Diesel Engine to the Yachting Field

Meeting Paper

By George A. Colley[1]

HULL characteristics, including dimensions, displacement, speed and seagoing qualities; cruising radius; probable annual mileage; first cost; and operating cost are the principal factors governing the selection of a suitable type of powerplant for marine usage. The paper considers them with reference to their special influence upon the application of the Diesel engine to yachts.

The question of making a Diesel installation is analyzed from an economic standpoint, and the relative operating costs for the various powers available for yacht usage are specified. Fuel consumption, reliability and other features of the Diesel are discussed, together with a brief mention of present Diesel installations and auxiliary equipment, the conclusion being that the Diesel engine offers great possibilities of advantages over those of other engines for yachts of the cruising type.

THE purpose of this paper is to cover the present application of the Diesel engine to the yachting field, and to show wherein such application can be used to the best advantage. Although the Diesel engine is by no means a "cure-all" for the yachtman's machinery problems, for certain classes of yacht, its installation offers advantages superior to those of any other form of propulsion, and definite qualifications usually determine the suitability of this type of powerplant for marine usage. The various factors affecting the selection of the type of power unit are (a) hull characteristics, including dimensions, displacement, speed and seagoing qualities, (b) cruising radius, (c) probable annual mileage, (d) first cost and (e) operating cost. Allied to all these points, of course, will be the type of service in which the yacht is to be used.

These determining features are interlocking to a greater or less extent in each design, and each installation is a separate problem to be judged on its own merits. Diesel equipment available up to the present time limits the hull size to a minimum of about 60 ft., although there is every indication that this minimum will be reduced. The upper limit of size has not as yet been reached as power units large enough to handle the maximum demands of the present-day yacht-owner are available.

Speed probably is one of the first characteristics that must be considered. When a speed of over 12 knots is desired in the smaller seagoing yachts, and more than say 16 knots in the larger ones, the use of Diesel engines is usually not advisable. It is then wise to go to the lighter, more compact gasoline units of greater power, to high-speed reciprocating steam-engines or to turbine units with water-tube boilers. The speeds noted above, however, are ample for all-round cruisers of moderate dimensions, the larger seagoing yachts or the full-powered auxiliary. The reasons for the above speed limitations are that the weights per horsepower, ranging from 85 to 190 lb. depending on the engines selected, raise the total hull-weight to such an extent that greater speeds are not desirable nor in most cases possible. Likewise the greater over-all engine dimensions have a similar limiting effect when compared with high-speed gasoline-engine installations.

TABLE 1 — RELATIVE FUEL-CONSUMPTION AND COST

Type of Prime-Mover	Fuel Used	Average Fuel Cost	Fuel Consumption per B.Hp-Hr.	Fuel Cost per Hr.	Fuel Cost per 1000 Hp-Hr.
Diesel Engine	Fuel Oil 22 to 32 deg. Baumé	$0.050 per gal.	0.450 lb. 0.060 gal.	$0.00300	$3.00
Gasoline Engine	Gasoline	$0.230 per gal.	0.800 lb. 0.114 gal.	$0.02620	$26.24
Steam: Oil-Fired Boilers Triple Expansion Reciprocating Engines	Fuel Oil 14 to 24 deg. Baumé	$0.040 per gal.	1.300 lb. 0.170 gal.	$0.00680	$6.80
Steam: Coal-Fired Boilers Triple Expansion Reciprocating Engines	Coal	$8.00 per ton $0.004 per lb.	1.800 lb.	$0.00720	$7.20
Steam: Oil-Fired Boilers Geared Turbines	Fuel Oil 14 to 24 deg. Baumé	$0.040 per gal.	1.200 lb. 0.156 gal.	$0.00624	$6.24

Costs

From an economic standpoint the items of first cost, operating period per season and operating cost, determine whether the Diesel installation should be preferred. The relative operating figures for the various powers available for yacht use are given in Table 1.

Lubrication charges against the Diesel engine average about 1 gal. per 1000 hp-hr., which is about 25 per cent less than the average lubricant consumption by gasoline

[1] Consulting Engineer, 5 E. 39th St., New York City, eastern district manager for the White Engine Works, Cleveland.

engines. Lubrication costs on steam installations are low, but are more than offset by the cost of stand-by charges, which in some cases run up to 25 per cent of the total fuel charges. With present Diesel-engine prices averaging between $75 and $85 per hp. and gasoline-engine prices, for engines capable of operating in the same service, ranging from $35 to $50 per hp., fuel oil at 5 cents per gal. and gasoline at 23 cents per gal., it is possible to determine the minimum number of operating hours that will warrant an owner installing Diesel machinery.

Assuming certain fixed charges against each installation per year, such as interest on initial investment, depreciation, insurance and maintenance, which will total about 20 per cent of the initial cost, and adding to these items the operating charges per year with varying hours of operation, a true comparison can be made. Calculations of this nature have been worked out on several installations during the past 2 years and show that, as between the gasoline and the Diesel engine, the maximum economical operating period for the gasoline unit is from 300 to 500 hr. per season. With steam units, the same method of comparison can be used and, figured entirely from the standpoint of economy, the cruising period necessary to warrant Diesel installation would extend to between 750 and 850 hr.

Fuel Consumption

From the fuel-consumption comparison given in Table 1 it will be seen that, for a given cruising-radius, the gasoline-driven yacht requires practically twice the weight of fuel necessary for the Diesel-driven yacht; that the oil-fired steam unit requires about three times and the coal-fired steam unit more than four times the weight of fuel. In the case of the gasoline yacht, this additional weight feature practically balances the saving in engine weight over that of the Diesel unit. The cubic capacity of the additional fuel also tends to balance the greater size of the Diesel engine.

As against the steam installation, however, the difference in weight and in volume is greatly in favor of the Diesel engine. Steam-operated craft require a large quantity of boiler feed-water which, of course, is entirely eliminated from the Diesel unit. This allows the designer to either decrease the displacement or increase the fuel-storage and, correspondingly, the cruising-radius. Steam installations, in addition, operate under the handicap of a much greater engine-room crew. Compared with a coal-fired boiler job, firemen, coal-passers and water-tenders are eliminated, with a corresponding decrease in the accommodation requirements, amount of food and the like. Compared with oil-fired boilers, water-tenders and firemen are eliminated, with a similar but not so great a saving.

If the owner wishes to take full advantage of the possibility of increasing the cruising-radius when comparing the steam and Diesel installations he can add from 200 to 300 per cent to the mileage without increasing the displacement, depending on the unit selected for comparison. As an example of the increased accommodation obtainable, a Diesel-powered yacht of 180-ft. overall length has practically the same owner's accommodations as a steam yacht of 225-ft. length.

Reliability

Formerly the matter of reliability was the bugbear of the Diesel engineer, but this has now been settled definitely. At present on the east and the west coasts of the United States some 25 or more Diesel installations, ranging from the smaller type of cruiser to seagoing yachts 180 to 200 ft. in length, are in service. These installations vary considerably in detail, some being full-powered, others auxiliary; in some cases, the Diesel-electric drive is used. All these yachts are operating with entire success, which has been attained by cooperation between yachtsmen, naval architects and engine builders. Reliability, in straight running and in maneuvering, has been obtained through careful design and installation of the main engines and of the auxiliaries. By carefully checking-up the details of the main engine, foundations, shafting and the like, vibration has been reduced to such an extent that it is no longer a factor.

The modern Diesel engine is accessible, easy of repair, cleanly and economical as regards wear on moving parts. Standardization of parts enables spares to be carried for quick replacement with a minimum of expense and time loss. With the cooperation of the American Bureau of Shipping and the insurance companies, the insurance rates are better than on gasoline installations and as low, if not better, than on steam installations.

Many of the yachts are used as ferries between New York City and Newport, R. I., Fisher's Island and other shore points and make several round-trips a week. Their ability to get under way on extremely short notice, coupled with the fact that one fueling will suffice for half a season's operation, is an obvious added advantage. Eliminating the necessity for frequent fueling, with its attendant objections, enables the yacht to be kept in shipshape condition with a considerable reduction in labor and expense. The annoyance and delay caused by coaling, ash-removal and the like are completely dispensed with, and wear and tear are reduced accordingly.

Present Diesel Installations

Three general types of Diesel installation are used at present: (*a*) the low-power installation on the smaller cruisers and auxiliaries where the engines are not directly reversible, and where maneuvering is accomplished by a clutch and reverse gear; (*b*) the direct-reversible installation where all maneuvering is done by compressed air, the engines being fitted with a double set of cams, one for ahead and the other for astern operation; and (*c*) the Diesel-electric drive, in which one or more Diesel engines provide the necessary power for generating electrical energy that, in turn, is transmitted to the driving motor or motors. In the last case the main generators are run continuously and all maneuvering and control is handled electrically. For certain installations in which the space available for machinery is divided-up, or where conditions require a propeller speed beyond the limits of the direct-drive Diesel or, in fact, for special installation of any sort, it is possible to obtain results with the electric drive that can be obtained in no other way. An example of this is the schooner yacht Alcyone. This vessel is equipped with a 350-shaft-hp. installation, consisting of two generating-units and one double-armature motor, in a space that would not have permitted a direct Diesel installation of over 250 hp. at an efficient propeller speed. The control is extremely flexible, especially at low speeds, and this point is one of the chief advantages of this type of drive.

Auxiliary Diesel Equipment

The importance of the auxiliary equipment in a Diesel installation cannot be overestimated. It is absolutely essential to the proper operation of the plant to have the auxiliaries balanced adequately to perform their

various functions. The average installation, in addition to the main propeller-equipment, consists of a suitable hand-started auxiliary capable of furnishing sufficient power to operate either the main or the auxiliary air-compressor, thus furnishing air for starting or in case the air has been drained on account of repairs or alterations to the air lines, tanks and the like. The air-compressor units can be driven either electrically or directly from a small engine. Electrical operation usually is favored, for with this method the small generator-unit can be used for emergency lighting. In small installations, one or two generating-units of 5 to 10-kw. capacity will take care of all the auxiliary power requirements. Usually units of this size are equipped to use both gasoline and kerosene fuel.

In the larger yachts, where an electrically driven ice-machine, a power-windlass, a boat-hoist, maneuvering-compressors and the like are to be handled, the installation of a larger generator-unit, to operate on the same fuel as that used by the main engine, is usually advisable. In some cases this is done in duplicate. Units of from 10 to 20-kw. capacity can be obtained that operate on the Lessner or some similiar principle and, for capacities from 20 kw. up, full Diesel units are available. Generally the air-compressors are in duplicate in the large installations, which naturally makes for reliability. The air-compressor units on the yacht Dolphin, with the air bottles grouped above, afford an instance of the possibilities of a neat and an accessible arrangement. In the Nourmahal's engine room, the circulating-water and the lubricating-oil pumps are attached to the main engines. This is conceded to be good practice within the power requirements of the yachting field, although in the larger commercial installations independently driven pumps are the usual arrangement. In this case, of course, they should be in duplicate.

In conclusion, when the yacht under consideration is of the normal cruising type and of moderate speed-requirements, in which the owner expects to cruise more than 400 hr. or more than 4000 nautical miles per year and wishes the maximum accommodation with the minimum operating cost, the Diesel engine offers possibilities in economy, cruising-radius and reliability that cannot be approached by any other form of prime-mover.

THE DISCUSSION

QUESTION:—Referring to electric-drive propulsion, at what speed is the propeller required to run?

GEORGE A. COLLEY:—At any speed desired. You should determine the best speed for the job, say 100, 175, 250 r.p.m. or whatever it may be. The electric motor is designed for a certain speed and will operate from that rate down through the intermediate speeds to zero. You control the number of revolutions per minute of the motor definitely, as you usually have from 25 to 35 points between full power and no power, and between full speed and no speed, at which you can operate it.

C. D. LEFEVRE:—Does the Diesel engine operate at a constant speed?

MR. COLLEY:—Diesel engines are designed to operate at a constant speed at all times, when used in connection with the electric drive. The usual practice is to mount the controlling exciters on the end of the generator shaft; the control station can be seated anywhere you wish.

L. M. WHITLOCK:—What are the limitations on size of small Diesel engines? One engine operating on the Diesel principle at the Motorboat Show had a 2¾-in. bore. Why have we not more Diesels with 2¾-in. bore?

MR. COLLEY:—We have built a number of engines with 5¾-in. bore, which is a very small engine, with air-blast injection. In the semi-Diesel engine, or the surface-ignition engine and, as some people call the other type, the preignition engine, as in the Leissner method, the engines can run in fairly small sizes. One small engine of about 7½ hp. per cylinder, from what I have seen of it, operates very well. I see no reason why such engines cannot be applied to the smaller boats. They have not been in operation long but I have no doubt that, within a year or two, we shall see many boats of the heavy-duty type, not high-speed boats, but comfortable cruisers in sizes considerably smaller than those mentioned previously.

H. W. SLAUSON:—Is the electrically driven boat controlled from the bridge or by signals to the engine room?

MR. COLLEY:—It can be controlled either way.

MR. SLAUSON:—Will the governors take care of variable loads on the engines?

MR. COLLEY:—The governors will take care of them under all conditions. We have recently completed a test on some 10 engines for the Coast Artillery Corps, in which the variation was kept down to from 1½ to 2 per cent under varying load conditions, which is better than is required ordinarily. Usually, the electric companies do not need such close regulation; 3 to 4 per cent generally is sufficient.

MR. LEFEVRE:—How close is the speed-control of the motor?

MR. COLLEY:—About the same.

MR. LEFEVRE:—What is the advantage of the electric drive, as compared with the Diesel, in direct maneuvering?

MR. COLLEY:—I think the direct drive is applicable in a majority of cases. The first electric-drive installation we had was in a schooner that did not have room enough to put the motor in the engine room. We could not get the shaft through from the engine room aft to the stern. We put the motor away aft, just ahead of the stern post, alongside of the center line, and the engine was forward in the hold. This arrangement was warranted by the conditions. In certain types of boat, a great quantity of power is used for other services than propulsion. This does not apply to the yachting field. In other installations where pumps or other power units require a large proportion of the total power generated, one of the generator-units may be required for this service. I think it can be said definitely that, except in special cases, the direct-drive type of yacht like that of the Dolphin or the Nourmahal, is the logical installation. The engine units are efficient, and give good propeller efficiencies at the speeds used. When better propeller results are needed, as in very slow boats where propeller speeds of about 90 r.p.m. are required, the electric drive will give much better results. When everything is normal I should say that the straight Diesel drive can be used.

QUESTION:—Has any experimental work been done with solid injection?

MR. COLLEY:—Yes.

C. F. SCOTT:—What is the highest speed on direct Diesel drive that is now considered economical for propeller efficiency in cruisers?

MR. COLLEY:—About 500 r.p.m., depending on the type of boat. We would not turn the propeller on an 800-ton boat like the Ohio at 500 r.p.m.; that would be much to high. About 250 or 300 r.p.m. would be as high as we ought to go. Practice leans toward that

(Concluded on p. 501)

Motor-Vehicle Wheel-Alignment

By John F. Duby[1]

New England Section Paper *Illustrated with* Drawings

SINCE accurate wheel-alignment is of much greater importance than has been realized generally and because so much confusion existed regarding proper methods of securing it, the author explains a method for obtaining correct alignment that will insure easy steering and cause the least amount of tire wear.

Correct wheel-alignment is defined and the differences between front-wheel and rear-wheel alignment-requirements are stated. "Toe-in" and "camber" are analyzed, their requisite values are discussed and the manner of determining them is explained. Axle-tilt and wheel-wabble are considered also in their relation to the subject, and a summary is given of the proper procedure to secure correct wheel-alignment.

ACCURATE alignment of the wheels of an automobile is of great importance. When it is realized that the cost of operating a car can be reduced by 5 to 50 per cent merely by making a slight adjustment that is already provided for on the tie-rod, it is difficult to understand why the subject of wheel-alignment has been so neglected. I visited not long ago nearly all of the automobile plants in Detroit, Flint, Pontiac, Toledo and Cleveland. I found that much confusion existed with regard to the subject. Until recently there has been no standard to follow.

After having investigated wheel-alignment very thoroughly, I will endeavor to give a logical answer to such questions as may be raised regarding the subject. Although different sizes and types of car cause varying conditions, I will give a short, easy method of calculating and allowing for the correct wheel-setting for all cars, so as to insure good steering and cause the least possible amount of tire wear. Contrary to the opinion of many, it is not necessary to sacrifice the tires to obtain good steering. A tire can be ruined much sooner by misalignment than it can by under-inflation; yet many drivers of cars use the utmost care in keeping their tires pumped-up to the proper pressure and pay practically no attention to the alignment of the wheels.

Some factors do not come directly under the heading of wheel-alignment, but they are connected with it so closely that we cannot treat the subject thoroughly without including them. For instance, wheel-alignment is affected seriously by axles, tie-rods, king-pins, radius-rods, steering-arms and the steering-gear. Even the spring-suspension plays a much more important part than most people realize, as will be shown later.

Correct Wheel-Alignment

Let us first determine just what constitutes correct wheel-alignment. To some it might appear that the two front-wheels should be parallel, the two rear-wheels parallel and each rear wheel directly in line with the front wheel on the same side. This would place the four wheels in such a way that a straight line could be drawn directly through the center of the two right-hand wheels, another line could be drawn through the center of the two left-hand wheels, and the two lines would be exactly parallel. If it were not for other conditions, this arrangement, which is shown in Fig. 1, would be ideal and would allow all four wheels to roll freely and cause the least possible amount of friction.

Rear wheels are adjusted very much as one would naturally expect. They should be parallel in every way; that is, each rear-wheel should revolve in a perfectly true circle, the two rear-wheels should be the same distance apart at the front and the back and also at the top and the bottom, and the axle should be at right angles with a line drawn through the center of the frame from front to rear.

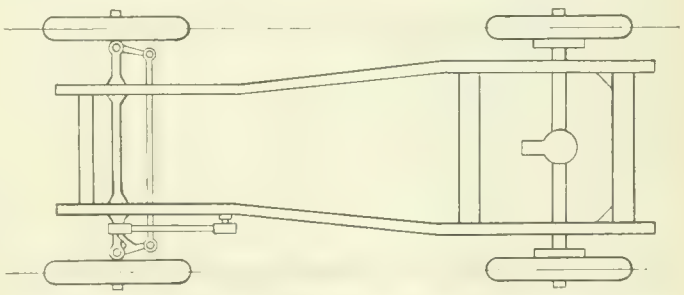


Fig. 1—Diagram Showing What Apparently Is Correct Wheel-Alignment

If the rear axle is not at right angles with the frame and the front-wheels are set perfectly straight, the car will go around in a circle instead of straight ahead. This tendency can be overcome by turning the front-wheels in the same direction that the rear-wheels are pointed. This will cause the car to travel in a straight line, but the rear-wheels will travel off to one side instead of following the front-wheels.

On some cars the rear axle is held in position by the rear springs. With this construction, it can be seen readily, it is necessary to have the two rear springs of exactly the same length so as to hold the axle square with the frame. If the spring-clips should become loose and allow one side of the axle to move backward or forward, the axle would not be square with the frame and, consequently, would be out-of-line. Another type of construction has radius-rods that hold the rear axle in the proper relation to the frame. These rods are provided with adjustments by which either or both sides of the rear axle can be moved forward or backward. On this type, it is necessary to have both radius-rods adjusted to exactly the same length. The rear axle and the drive-shaft housing on another type are bolted together and make a T-shape unit. In some types, this construction is reenforced by having the springs act as radius-rods but, on other types, the springs are hung in such a way as to give free action to the rear axle; in the latter case the drive-shaft housing is depended upon to hold the rear axle in the proper alignment. A severe bump on either wheel might bend the drive-shaft housing; in this case, the rear wheels would be parallel with each other but the axle would not be at right angles with the frame.

[1] John F. Duby Co., Mattapan, Mass.

In the former carriage construction, if the carriage were pushed through sand or mud the axle would tend to bend backward at each end; this would bow the center of the axle forward and cause the wheels to toe-out. This condition was counteracted in carriage construction by the fact that the shafts, or the pole, were always attached to the axle at two points, each about midway between the king-pin and one of the front wheels. Since the power was applied at these two points instead of at the center, this prevented the axle from bending backward at each end.

In automobile construction, even with the king-pins set close to the wheels, a slight tendency for each spindle to bend backward as the car is being propelled forward still exists and, if the wheels were set perfectly parallel when the car was standing still, they would immediately toe-out when the car was started forward. This toeing-out would increase with the speed of the car, or as the road conditions became such as to cause more resistance to the forward movement of the front wheels. Right here is one of the principal reasons for toeing-in the front wheels. But this tendency to bend backward varies with different types of construction.

Camber

Other factors have a direct bearing on the amount of toe-in required; one of these is "camber." An understanding of camber is absolutely necessary when determining the correct amount of toe-in. In carriage construction it was common practice to arch or crown the axles. The bowing-up in the center of a solid bar that extended through the hubs of the wheels caused the wheels to be closer together at the bottom. This was commonly called camber.

In automobile construction also, the wheels are set closer together at the bottom than at the top, but it is done in an entirely different way and for a different purpose. Instead of cambering the axle, the spindles are designed so that they are not at right angles with the king-pins. This gives the same effect as actual camber, and we will continue to use that term.

The principal reason for camber is to bring the wheels into contact with the road at a point directly under the center of the king-pins as nearly as that is possible; this still further decreases the tendency for the spindles to bend backward as the car is being driven forward. This would decrease greatly the necessity for toeing-in except for the fact that setting the wheels at this angle causes each wheel to act as a cone where it comes into contact with the road and the tendency of a cone is to roll around in a circle. Therefore, this very cambering, or the setting of the wheels closer together at the bottom, necessitates toeing-in in itself; so, as the necessity for toe-in due to camber increases, the necessity for toe-in due to the spindles bending backward decreases. One just offsets the other, and the necessity for toe-in remains exactly the same.

Another reason for both toe-in and camber is as follows: The weight of the car is carried on the spindles, the spindles are held in position by the king-pins and the weight of the car tends to press outward at the bottom and inward at the top of the king-pins; this causes a binding strain on the king-pin bushings. By bringing the wheels into contact with the road at a point nearer to a direct line with the center of the king-pins, this tendency is decreased. It is decreased still further by setting the wheels closer together at the front, which causes the wheels to pull-in at the bottom, due to the tendency for the wheels to roll toward the center. This

makes a car easy to steer. If the wheels were toeing-out in addition to the effect due to the weight of the car, the wheels would be pulling outward at the bottom; this would increase the binding strain and make a car hard to steer.

We now have several good reasons for both toe-in and camber, but we must remember that a greater amount of camber does not necessarily require a greater amount of toe-in; because, as the camber increases, the tendency for the wheels to spread at the front decreases.

Other Factors Affecting Toe-In

Other factors materially affect the amount of toe-in. First, the amount of pressure required to spring the steering connections. A car with stiff spindle-arms will require less toe-in than one on which the wheels can be sprung outward easily at the front. Second, the size of the wheels. Large wheels require more toe-in than small wheels. Third, the size of the section of the tire. A 32 x 4½-in. tire requires more toe-in than a 32 x 3½-in. tire. Fourth, the point at which the tests are made. If a car were tested for toe-in by taking the readings from the tires and it showed ¼-in. toe-in, the same car tested from the felloes would show considerably less than ¼-in. toe-in because the front and back readings would be taken much closer together.

Method Employed

It might appear necessary that each service-station employ an engineer to determine the amount of toe-in and camber required on each car, but this is not the case. I offer a quick, easy method of eliminating all this confusion, so that it is not even necessary to use a chart showing the amount of toe-in required on different cars. This method takes care of all these varying conditions, treats all cars alike and yet actually gives to each different type the correct amount of toe-in without any special allowances.

Regarding the variation in the stiffness of the different spindle-arms, by pressing outward on the front of both front wheels, those cars that are equipped with stiff spindle-arms and tie-rods will not be affected but, if the car is equipped with parts that are easily sprung, the wheels will be pushed outward at the front and the friction of the tires will prevent them from coming completely back to their normal position, varying in exact accordance with the amount that those parts can be sprung. If the wheels are tested for toe-in in this position, they actually will be given more toe-in than what is shown on the gage, thereby compensating automatically for that springy condition and making it possible to give the same allowance for toe-in on all cars.

As to the size of the wheels, if all the readings were taken at the center of the wheels, a different allowance would need to be made for each different size of wheel but, by taking all readings at a distance of 9 in. from the floor, the large wheels will be tested farther below their centers than the small ones and, if the same allowance is given on the gage, the large wheels automatically will be given more toe-in than the small ones, thereby again making one allowance for toe-in on all sizes of wheel.

If some cars were tested from the felloes and some from the tires, a different allowance would be necessary and, on wire wheels and disc wheels, the readings must be taken from the tires because there are no felloes. Therefore, I recommend taking all readings from the tires and not from the felloes. This gives one method of testing on all cars, again making it possible to give one allowance for toe-in on all cars.

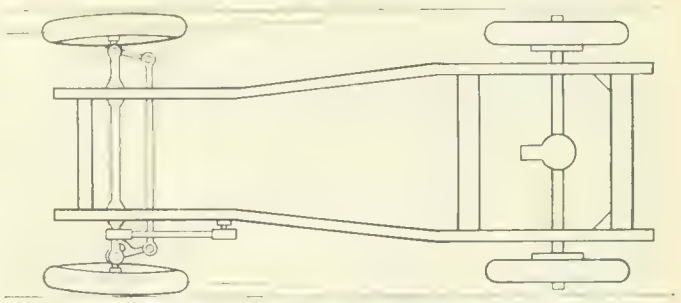


Fig. 2—Diagram Showing the Relative Wheel-Positions That Have Been Found To Be Satisfactory

The measurement from wheel to wheel should be taken from the tire at the front, 9 in. from the floor. The car should then be moved forward far enough so that the second reading can be taken from the same identical part of the tire 9 in. from the floor at the back. This eliminates any possible chance of getting an inaccurate reading due to a lump on the tire, a crooked rim or a crooked wheel. If the readings were taken from two different points on the tire or the wheel, this would be very likely to give an inaccurate reading for spindle and tie-rod adjustment due to a slight inaccuracy in the tire or to a crooked felloe, rim or wheel; the felloes very rarely run perfectly true, even on new cars.

As to a 32 x 4½-in. wheel requiring more toe-in than a 32 x 3½-in. wheel, it will be found that if the readings are taken from the part of the tire that offers a flat surface for the end of the gage or measuring apparatus, the two readings will be taken closer together on the 32 x 4½-in. tire than they will on the 32 x 3½-in. tire, thereby automatically giving more toe-in to the 4½-in. tire than to the 3½-in. one, again making it possible to give the same allowance for toe-in on all cars.

We now have a method by which all of these varying conditions are automatically taken care of and we are able to give the same allowance for toe-in on all cars. We will next determine just what that amount of toe-in should be.

Amount of Toe-In

After taking this matter up with the automobile and the tire companies we still lacked sufficient information to be able to say definitely just what the correct amount of toe-in should be. One company would specify ⅜-in. toe-in and another company, using practically the same construction and the same size of wheel, would say ⅛-in. toe-in. We then proceeded to try out each of the recommendations. After much experimenting, we finally concluded that no definite amount of toe-in could be stated unless we could compensate in some way for the amount the wheels would spread at the front while traveling on the road.

By attaching an apparatus that would give the exact setting of the wheels at any speed on the road, we found that some makes of car, having an initial toe-in of ¼ in. and no play in the bushings, would be running perfectly straight at 25 m.p.h. On other makes of car having an initial toe-in of ¼ in., we found that they would still remain at almost exactly ¼-in. toe-in at 25 m.p.h. We found also that, by pressing outward on the front of both front wheels, we could spring the wheels apart on some cars as much as ½ in., but that the friction of the tires on the floor would prevent them from coming completely back to their normal position after they were let

give this small toe-in almost exactly equaled the position that would take when traveling along the road at a normal speed and, by taking the readings in this position and allowing 3/16-in. toe-in, we obtained excellent steering qualities and the tire wear was not excessive. In addition, we found that if more than 1/4-in. toe-in was given to a car equipped with stiff steering-connections, the life of the tire would be decreased materially and no advantage was gained in steering. In fact, we found that these cars would steer and handle exactly as well with 1/4-in. toe-in as they would with 1/8-in. toe-in, and that this applied to every size and type of car tested. Therefore, anywhere from 1/8 to 1/4-in. toe-in would be the correct amount, provided, however, that the readings were taken from the tires at 9 in. from the floor.

To summarize, if you will press outward on the front of the front wheels, then let go of them and allow them to come back as nearly to their normal position as the friction on the tires will permit, then take the reading from wheel to wheel, on the tires, 9 in. from the floor, then move the car forward until that same part of the tire arrives at a position back of the axle, 9 in. from the floor, and then take the second reading from wheel to wheel, the second reading should be 3/16-in. greater than the first reading, with a tolerance of 1/16-in. either way. This means from 1/8 to 1/4-in. toe-in on all cars.

In some designs, the king-pin is set out into the hub so that, with a slight amount of camber, the wheels actually come into contact with the road at a point directly in line with the center of the king-pins. In this case, obstructions on the road or heavy mud or sand have no tendency to bend the spindles backward. If all cars were of this design, the amount of toe-in could be decreased somewhat, but a slight tendency for the wheels to spread apart at the front would still remain; hence, 3/16-in. toe-in is not too much, even for this type of construction.

Amount of Camber

The amount of camber is not a vital factor. A car will steer perfectly well with either 1 or 3 deg. of camber. In fact, different engineers allow anywhere from 0 to 4 deg. of camber and no appreciable difference in the steering or handling of the car is apparent; but, as the amount of camber increases beyond 2 deg., it begins to affect the wear of the tires. Therefore, I say that 2 deg. is sufficient.

All that is necessary to test for camber is to suspend a plumb line from the outside of the tire at the top and measure the distance from the line to the tire at the bottom. The line should be hung so that it will pass the center of the wheel at a point 4 in. in front of the hub. This is done so that the measurement will not be taken from that part of the tire which is flattened out on the floor by the weight of the car. When wheels are tested in this manner, 2 deg. of camber on a 34 x 4-in. tire will show exactly 1 in. from the plumb line to the tire on each wheel at the lower end. Larger wheels, with the same degree of camber, would show more; smaller wheels would show less, but the difference would be very slight.

The method of testing rear wheels is the same as that of testing the front, except that the first reading should be taken from the tires at the back; then, the car should be moved backward instead of forward. Of course, no pressing outward of the wheels is necessary. The rear wheels should have no toe-in and no camber; consequently, the height at which the readings are taken on rear wheels is not important.

Testing Instruments

While no particular gage has been mentioned for testing toe-in, I believe the one best adapted to test in this way is the one that is placed between the wheels at the front and is held in position by a spiral spring that presses each end of the gage firmly against the tires, as shown in Fig. 3, the pendant chains indicating the proper height from the floor. The pointer is set at zero. The gage is then left in position while the car is being moved forward and is automatically carried to the position for the second reading. The pendant chains indicate when the car has been moved far enough to reach the proper height at the back of the wheels. The pointer will then register the exact amount of toe-in without necessitating any calculations; consequently, no possible chance of making a mistake is present.

The method of testing to see if the rear axle is at right angles with the frame is to measure from a point exactly at the center of the front axle to each of the two rear brake-drums. The distance should be exactly the same on both sides.

Although the adjustment for toe-in is usually made from the tie-rod, it must be borne in mind that if a spindle-arm is badly bent it cannot be corrected by shortening or lengthening the tie-rod. This is because each spindle-arm should be set so that it will point directly toward the center of the rear axle, to give the correct degree of angularity to each front wheel when the car is turning a corner. The wheel that is on the inside of the curve is cutting a smaller circle; therefore, it must be turned at a sharper angle. This is accomplished by having the steering-arms point directly toward the center of the rear axle.

Trueness of Wheels

It goes without saying that each front wheel, as well as the rear, should revolve true on its axis. The best method for testing this is to jack each wheel up and turn it. If the wheel is not running true, it can be detected readily in this way. Wheels that do not run true in this way are called wabbly wheels; but, although they do other bad things, they do not affect the tire wear. A wheel will always roll in the direction that is exactly at right angles with its axis, regardless of whether it runs true on its axis or not. If the wheel is not running true on its axis it will leave a crooked track, but the wheel will not tend to crowd to either one side or the other.

The principal disadvantage of wabbly wheels is that the wheel constantly tends to right itself, due to the centrifugal force, and this tendency increases with the speed of the car. By actual test, a wheel that was turning at a speed of 500 r.p.m. and was 1 in. out of true, was so affected by this centrifugal force that it ran almost in a perfectly true circle but, in doing so, it caused the hub to wabble although the hub ran perfectly true when the wheel was being turned at lower speeds. This condition has a tendency to "crystallize" the spindles and the steering-arms, especially on a car that is likely to be driven at a high rate of speed. A wheel running 1/8 in. out of true in this way would do no serious harm, but I would object seriously to driving a car at a high rate of speed if a wheel were more than 1/8 in. out-of-true in this way.

Comparison with Other Methods

Regarding how much toe-in this 3/16 in. taken 9 in. from the floor would amount to if taken on a level with the center of the wheel, a 30 x 3½-in. wheel tested from the tires and given 3/16-in. toe-in at 9 in. from the floor

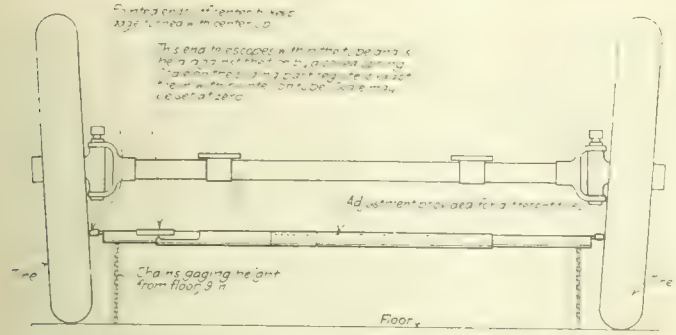


FIG. 3—GAGE FOR TESTING THE AMOUNT OF TOE-IN

This Gage Is Adjustable for Different Sizes of Tire and the Chains Indicate Whether or Not the Gage Is Set at the Proper Height from the Floor, 9 In.

would be exactly 3/16 in. if taken from the center where the tire and rim meet. It would be 1/64 in. less if taken level with the center on the felloes, and 1/64 in. more if taken level with the center on the tires. A 33 x 4½-in. wheel given 3/16-in. toe-in when tested from the tires at 9 in. from the floor would have exactly 3/16-in. toe-in if taken level with the center on the rim, but would be 1/64 in. less if taken from the felloes, and would be 1/32 in. more if taken from the tires. A 36 x 4½-in. wheel given 3/16-in. toe-in, when tested from the tire at 9 in. from the floor, would be exactly 3/16 in. if taken level with the center on the felloes and would be approximately ¼ in. if taken from the tires.

FRONT-AXLE TILT

The tilting of the front axle, it is generally agreed, is done to give the wheels a "caster" effect; that is, to bring the wheel in contact with the road at a point back of a line drawn through the center of the king-pins. This is done for three purposes. First, to avoid any possibility of the king-pin becoming pitched in the opposite way, which would cause serious results. Second, to cause each wheel to follow the king-pin in case the tie-rod should break or become disconnected. Third, if the king-pins were not pitched in this way, when driving through sand or mud that part of the wheel pushing against the sand or the mud would be so far in front of the king-pin that the wheels would tend to turn sidewise. The amount of tilt given to the front axle varies slightly with different types of construction, but between 2 and 3 deg. will give excellent results on all cars.

AXLE-TILT AND WHEEL-ALIGNMENT

While the tilting of the front axle does not come directly under the heading of wheel-alignment, it affects wheel-alignment to the following extent. The wheels are closer together at the bottom on practically all cars; on some cars as much as a 3-in. difference exists, while the toe-in is only 3/16 in. Any condition that would allow the angle of the front axle to change might very easily change part of that 3 in. of camber to toe-in, thus affecting the amount of toe-in seriously. In some types of construction the angle at which the axle is tilted is different when the car is loaded from what it is when the car is empty. On this type of construction it is very important to test the wheel alignment after the body has been placed on the chassis, as the weight of the body is enough to affect the amount of toe-in.

The amount that the front axles are tilted varies. Insufficient tilt will cause the wheels, when turned in either direction, to pull hard in that direction. For instance, in turning a corner, difficulty is experienced in bringing the wheels back to a straight-ahead position if the tilt is insufficient. The correct amount of tilt will have a tendency to bring the wheels back to a straight-ahead position after turning a corner, but too much tilt will cause a noticeable tendency for the wheels to turn toward the side of the road when being driven on either side of the crowned road.

WHEEL-WABBLE

Another condition that is caused by too much of the caster effect is a tendency, when driving at certain speeds, for the wheels to change their course rapidly from right to left and to continue to alternate until stopped either by changing the speed of the car or by a change in road conditions. This tendency is increased greatly if the connections between the steering-gear and the wheels are of a springy construction. On some cars, a spring is located at each side of the ball-joint on one end of the tie-rod. This condition, even with the correct amount of caster effect, will sometimes cause the wheels to alternate from side to side in the manner just stated. This condition very often can be corrected by removing one of the springs mentioned and placing a solid block in its place. It can be improved still further by having one spring at each end of the drag-link, one allowing the distance between the two ball-joints to lengthen and the other allowing it to shorten if the necessity arises, but each one always coming back against a solid stop.

On some cars the drag-link and the front spring are hung in such a way that, when the spring is depressed, the wheels must turn to one side, the steering-wheel must turn in the hands of the operator or something must bend. When a car is being driven on a wavy road, this makes the steering very uncertain as the wheels will turn from one side to the other, not rapidly as in the case in which the caster effect is too great, but with each toss of the car. Another bad effect resulting from this condition is that, if the steering-gear is irreversible and the wheels fairly heavy, the steering-gear and the drag-link bearings loosen rapidly. This very often can be remedied by bending the arm at the front end of the drag-link up or down, so that the front ball-joint will be in a direct line with the rear ball-joint and the front spring-bolt, as in Fig. 4.

SUMMARY

A car with the wheels in proper alignment should have the rear axle at right angles with the frame and the rear wheels parallel with each other. The front wheels should be the same distance apart at the bottom as the rear wheels, but farther apart at the top than the rear wheels are. The front wheels also should be toed-in 3/16 in. after having been sprung outward and allowed to come back as far as the friction of the tires will allow. The front axle should be tilted so that the king-pins will be farther forward at the bottom than they are at the top. The spindle-arms should point toward the center of the rear axle, and the front and the rear joints on the drag-

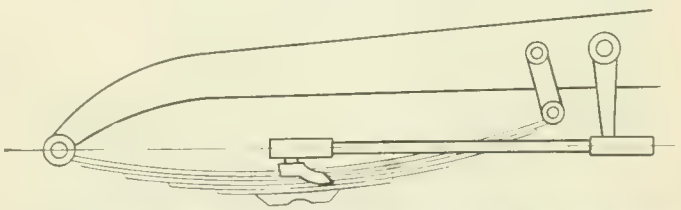


FIG. 4—HAVING THE FRONT AND REAR BALL-JOINTS AND THE FRONT SPRING-BOLT IN A STRAIGHT LINE AS SHOWN WILL CURE WHEEL WABBLE

and should be in a direct line with the front spring-bolt.

The best method of testing for toe-in is to take the reading from wheel to wheel on the tires, 9 in. from the floor, at the front, then to move the car forward and take the reading from the identical spot on the tires, 9 in. from the floor, at the back. The importance of taking the reading from the same spot on the tires cannot be overestimated. The rear wheels are tested in the same way, except that the car is moved backward.

The method of testing for camber is to suspend a plumb-line over the outside of the tire 4 in. in front of the hub. The method of testing the rear axle to see if it is square with the frame is to measure from the center of the front axle back to each rear brake-drum. The distance should be the same on each side.

All these features are essential to good steering and to the safe and economical operation of an automobile. Every shop should be equipped with adequate means of testing for each of these different conditions. I sincerely hope that testing for wheel-alignment with a string or a stick has practically been discontinued.

THE DISCUSSION

QUESTION:—To what extent is wheel-alignment affected by smooth roads and by heavy or rough roads?

JOHN F. DUBY:—Heavy mud or sand would require more toe-in than a smooth road, if driving through it all the time, but we must come as near as possible to meeting all conditions. I use a 1/16-in. tolerance in either direction from the 3/16 toe-in. Differences in the road conditions would rarely make more than a 1/8-in. difference in toe-in; so, even on heavy roads, the toe-in probably would not be more than when running straight on smooth roads. In mud or sand it makes only a slight difference if the wheels toe-out some, because they have a chance to give without slipping or wearing the tires. We should consider the conditions under which we do most of our driving and have the wheels adapted to both hard and soft roads; if adapted to one kind of road only, they will slip and grind the tires on another kind of road.

QUESTION:—It is noticeable that one wheel seems to be the one that wears the tire, when both wheels are out of line. What does this indicate as to toe-in?

MR. DUBY:—If the wheels toe-out, almost always the left front-tire wears; if they toe-in, the right front-tire will wear because most of our driving is done on crowned roads; the right tire pushes toward the center and the left tire toward the side. The left tire has the advantage. This is more noticeable in a light car in which a man drives nearly alone. There the weight on the left side of the car is more and that holds the left front wheel down; so, it takes the course in which it is pointed, and the right-hand tire takes the slip. This condition was not so noticeable with the right-hand-drive cars. The difference in the weight on the right side equalled the disadvantage at which the right-hand wheels were in pointing toward the center of the road and equalled the amount of slip on the wheels.

QUESTION:—Does the amount of tire-inflation play any part in making tests for wheel-alignment?

MR. DUBY:—Tires should be pumped to the pressure at which a man drives a car before making the tests because if the pressure is so low that the tires flatten, the wheels, when turned apart at the front, will stay apart more than if the tires are pumped hard. But if a man drives with the tires not hard, the spindles will tend to bend backward; so, if one drives with a low tire-pressure, the wheels should be tested when they have low pressure to give the best results.

QUESTION:—Regarding the changing of the spring arrangement in the tie-rod with the idea of correcting shimmying of the wheels, should the angle of front-axle tilt be changed?

MR. DUBY:—This condition, even with the correct amount of tilt to the front axle, will sometimes cause shimmying. Therefore, I say that one is as much responsible as the other although, if the axle does not tilt, it is almost impossible to get the shimmying conditions to continue on a smooth road.

QUESTION:—When the wheels are pushed apart before measuring, does the degree to which they return vary?

MR. DUBY:—No. If a weak man pushes the wheels apart, they come back nearly to their normal position after he lets go. If a strong man pushes them apart, they will still return nearly to the position they started from. If one were to hold the wheels while making the test, it would make a difference; letting go, they will always come back nearly to the original position.

QUESTION:—What effect has the friction due to the character of floor surface on the final position of the wheels after being pushed apart? What is the difference between a greasy floor and a cement or wood floor free from grease?

MR. DUBY:—A greasy floor causes a difference, but a wood or a concrete floor makes practically no difference.

QUESTION:—When the drag-link is located close to the wheel, does that make much difference?

MR. DUBY:—When the drag-link runs crossways of the car, the lower end of the arm that extends from the steering-gear should be nearly in line between the two ends of the tie-rod or, at least, so that the drag-link will run almost level from the steering-gear to the spindle-arm. Otherwise, if the steering-gear were on the left side and the drag-link at the right and if the end connected to the steering-gear were higher, the drag-link would tend to push out in going down and turn the car to the left. The drag-link should be kept fairly level.

QUESTION:—Does center-point steering make a difference in the amount of camber required?

MR. DUBY:—The tilting of the king-pin outward, away from the center, will not affect the amount of camber; neither will it affect the tendency for the spindle to bend upward; because, although the center of the king-pin points toward that part of the tire that comes in contact with the road, if a plumb were dropped from the center, it would strike the road at a point inward from the center of the tire on the road. The necessity for camber would still exist and also of toe-in. Their requirements would be practically the same. The tendency for the spindle-arms to bend backward would be decreased in that construction, but the necessity for toe-in and camber is the same.

QUESTION:—How do front-wheel brakes affect wheel-alignment?

MR. DUBY:—So far as I have examined them, on all the cars, I believe, that are now in Boston and on at least one foreign car, front-wheel brakes will not affect wheel-alignment in any way except that they make it necessary to use stiffer spindle-arms than we use at present. Front-wheel brakes do not affect wheel-alignment because, on all cars of which I know, the king-pin is pointed outward at the bottom, thus bringing its center in line with the point at which the tire strikes the road. When using front-wheel brakes, the king-pin must be set out so that it will be in line with the center of the tire where it comes into contact with the road.

QUESTION:—I have had the right-hand front-tires wear concave on the outside during the past year; the center

remained in perfect condition. What is the reason for this?

MR. DUBY:—If the tires wear on the outside of the right front-wheel, that is almost a sure sign that the wheels are not perfectly lined-up. Some would say that the wheels are perfectly adjusted if 3/8-in. toe-in is allowed, the reading being taken from the felloes at the center, but any car equipped with stiff arms will not stand 3/8-in. toe-in if the readings are taken from the felloes. That will cause tire wear, and it cannot be remedied until the amount of toe-in is decreased.

QUESTION:—What about the cupping of tires? Tires wear in waves.

MR. DUBY:—The general practice of cambering, or setting the wheels closer together at the bottom, is thought by many not to affect tire wear, but after 2 deg. of camber, the "cupping" conditions mentioned are produced because the wheel strikes the road before it has completed its inward travel as it goes toward the bottom. It must either slip or distort the tire as it approaches the bottom. It slips until the pressure on the tire is sufficient to hold it from slipping; then, as it slips, it has to slip back as the tire leaves the road. Therefore, a double slip takes place, unless one is driving on a crowned road so that the wheels make contact with it at right angles; then, the wheels crowd from the center, and some tire scuffing results. A tire with a long crossbar would take a good grip on the road as the tire rolls from the point of contact to the point at which it leaves the road; a short crossbar would take the slippage. On tires having uniform knobs or buttons, one end of each knob will wear, leaving the other end practically not worn at all. This is due to the camber effect. As the car is driven, the slippage all comes from the time the tire comes into contact with the road until it reaches the bottom. If a car is being driven at a high rate of speed, most of the time the tire, as it leaves the bottom and approaches the point of leaving the road, does not touch the road at all in some cases. I have been told, by engineers present when tests were made, of a picture of a tire that did not touch the road from a point a short distance back of the center; and to where it touched the road in front of the center was four times as great a distance because it takes time for a tire to resume its shape after it has been depressed. At a high rate of speed, that part of the tire has been carried away from where it would come into contact with the road.

R. E. NORTHWAY:—I had a car 5 years ago that showed bad tire wear on the right side. I had a replacement and tested the wheels. Finally, I had the springs taken off and found that, from the center of the front eye to the center-bolt the right-hand spring was 1/4 in. short and the left-hand spring 1/8 in. long, a difference of 3/8 in. I remedied this by getting two springs that matched. Tire wear ceased at once. Little things enter into the proposition of wheel-alignment. Differences of camber and of springs make a difference in both tire wear and wheel-alignment.

MR. DUBY:—Perhaps the trouble Mr. Northway mentions was corrected in some other way, while the work on the springs was being done. I see no reason why having one end 1/4 in. farther back than the other would cause any tire wear. If the front axle is farther back on one side than on the other, both of the wheels point ahead and will roll perfectly freely until such time as they have to go round a corner or in a circle. Then they will be out-of-line because the two spindle-arms do not point directly toward the differential. If the rear axle were from 2 to 3 in. out-of-line, that condition would be serious enough to cause tire wear, but I do not see how 1/4 in. could make any difference. I have seen the wheel-alignment changed 1/4 in. by putting a new radius-rod on the front end of a car, because, in putting the rod in, the tilt of the front axle was changed. In the case Mr. Northway cites, putting in a new spring may have changed the tilt. If we turn the front axle one-quarter turn, the wheels toe-in the full amount that they were originally cambered. On one car that I saw in Detroit, they tested the wheel-alignment before putting on the body and allowed 1/4-in. toe-in, and the tire wear after the car left the factory was considerable. I tested one of the cars with the body on and found it to be toeing-in 3/8 in. A sedan car toed-in 7/16 in. We tested 10 or more out of a row of cars, and found they averaged more than 1/4-in. toe-in on each one. I took a pointer, for testing, placed it between the wheels and jumped the body up and down, the pointer moved in and out almost 1/4 in. It was decided that it was best to test wheels after the bodies were installed, instead of before. The tilt was changed after the weight was added to the car. One make of car, having an original toe-in of 1/4 in., will be toeing-in 5/16 in. with five people in the car; however, a difference of 1/16 in. will cause no serious harm.

QUESTION:—Is there any direct proportion between camber, tilt and toe-in?

MR. DUBY:—As stated in my paper, by increasing the amount of camber, the wheels are brought into contact with the road at a point nearer to being under the center of the king-pin, thereby eliminating one reason for toe-in; but, by cambering, we make a cone of the wheel at the point where it comes into contact with the road, thus adding a different reason for the toe-in and one offsets the other. The amount of toe-in will be the same, regardless of the camber. I have tried this out thoroughly and am well satisfied on that point. The wheel alignment is not affected by the tilt, so far as measuring when cars are standing still is concerned. If the degree of tilt is changed, that changes the amount of toe-in. In other words, the degree of tilt does affect the wheel-alignment by causing shimmying. That is not a difficult defect to discover in measuring wheels when standing still, but it affects the driving and the steering. The amount that wheels are cambered will not affect the amount they should be tilted. The amount the axle is tilted, if kept within reasonable bounds, will not affect the amount that the wheels should toe-in.

QUESTION:—Considering a left-hand-drive car, what is the proportion of cars that show the most wear on the right-hand front tire?

MR. DUBY:—Neither the wheel nor the tire knows which steering-arm that steering-gear is connected to. The tie-rod is holding one arm just as rigidly as it does the other, unless the tie-rod should be very springy and bowed down in the center. On that type more toe-in will be required, due to the fact that, as the car goes along, the tie-rod will bow down more as the car goes faster; so, we must give that car more toe-in, but it is done automatically. The tie-rod springs down and comes back; therefore, if the testing is done right, no difference as to tire wear will be noticed.

MR. NORTHWAY:—Mr. Duby suggested that we provide a caster effect of 3 deg. We made some tests on that in bus work up to 4 deg.; this increased the ease of steering, but certainly increased the shimmying effect. We found that 2 deg. was the maximum we could allow safely. A caster effect of 3 deg. was too much for high-speed work and rough roads. The wheels would wabble and we could not control it.

MR. [illegible]:—The condition may have been due to this very thing that I mentioned about two springs in one end of the drag-link. This gives a steering-gear that does not necessarily come back to the same spot, but if we put one spring in each end, with one allowing the drag-link to lengthen and the other permitting it to shorten, the steering-gear comes back to a stop, and we will have the link so it will always come back to the same point and correct the tendency to rock. Possibly, on a 37-in. tire, 3 deg. of camber would be too much. I have not tested with so large a tire. Most of my testing has been on smaller tires.

MR. NORTHWAY:—All our tests were made with drag-links that were equipped with one spring in each end, one allowing the link to lengthen and the other allowing it to shorten.

THE PRICE OF AGRICULTURAL PRODUCTS

THE average agricultural output in the first decade of this century was only 11 per cent more than in 1899; while in manufactures it amounted to 34 per cent. In 1909, the index of agricultural production stood at 118 and manufactures at 163. The population of the country in this same period had grown more than 20 per cent. Nearly all of this addition to our people was found in cities and towns. Of the 15,000,000 people who had been added to our numbers, more than 12,000,000 became city dwellers. For the 20 years from 1899 to 1919, the volume of farm products had increased by 35 per cent, while the output of manufactures had grown by more than 100 per cent. Our population in the same time had become 40 per cent larger, while the dwellers in cities and towns had increased by 60 per cent.

From 1899 to 1909, freight rates were practically stationary; they did not join in the upward movement of prices. In fact, this situation continued until the end of the year 1917. Not until 1920 were freight rates raised to the level of other prices. The revenue per ton of freight moved 1 mile had been 1.232 cents in 1880. From that level it fell to 0.729 cents in 1900 and remained practically stationary until 1917, when it stood at 0.717 cents. In March, 1921, it was at 1.61 and in 1923 it is 1.10 cents per ton-mile. The effect of this failure to adjust freight rates to the general movement no doubt had much to do with the rapid increase in farm prices and in land values.

In 1900 came the Boer War and in 1904 the Russo-Japanese War. Both these conflicts had the effect of stimulating the demand for American farm products. The nations involved in these wars were able to command credit with which to buy the things they needed. The three decades of peace and of industrial development that had preceded had placed the world in a position where Government bonds were readily absorbed by the international money market. In addition to these military conflicts, Europe, like ourselves, was enjoying an unprecedented industrial development. Mining, manufacturing and construction work were active and were yielding large profits. Population was increasing. The growth of cities is not alone an American manifestation during the first two decades of this century; it was universal in the Western world. All of this accentuated the tendency of demand for agricultural products to outrun the supply at the old prices.

For many years people have moved from the farms to the cities; and for many years, too, people who came into this country as immigrants have settled in our industrial centers rather than on our farms. By this process the number of people in cities and towns grew from about 45,000,000 in 1899 to almost 75,000,000 in 1919; while the number of people on farms remained almost stationary at not far from 30,000,000. The former had to be fed by the latter. As a result of this disparity in the growth of population and the consequent disparity in the volume of agricultural production as compared with industrial output, the prices of agricultural products rose more rapidly than did those of other things. Unless all precedent fails, the renewed movement of people from the farms to the cities, which has been in progress since the revival of business from the recent depression, will do more to restore the balance that the farmer seeks than any legislative action can possibly accomplish.—Prof. David Friday, New School for Social Research.

CENSUS OF VEHICLE INDUSTRY

THE reports made to the Bureau of Census by the manufacturing establishments in the United States show that the value of their products aggregated $3,653,283,000 in 1921, as compared with $62,041,795,000 in 1919, a decrease of 30 per cent. Compared with the value of products reported for 1914, this represents an increase of 80 per cent and was due largely to the rise in prices. The average number of wage-earners employed in 1921 was 6,946,564, or 23 per cent less than the number reported for 1919. The difference between the figures shown for 1914 and 1921 is very little. The census statistics for 1921 relate only to establishments having products valued at $5,000 or more, whereas at prior censuses the corresponding limit was $500.

The accompanying table summarizes the statistics for 1921, for vehicles for land transportation. It will be noted in this connection that while the carriage and wagon factories, measured by value of product, are more than double the plants building motor vehicles, the latter employ a much larger force.

STATISTICS OF VEHICLES FOR LAND TRANSPORTATION FOR 1921

Industry	Number of Establishments	Average Number of Wage Earners	Value of Products
Motor Vehicles	385	143,658	$1,671,386,976
Motor-Vehicle Bodies and Parts	1,947	69,119	408,016,532
Carriages and Wagons, Including Repairs	826	7,797	31,658,791
Carriage and Wagon Materials	141	2,747	10,787,177
Carriages and Sleds, Children's	89	5,460	21,716,839
Cars, Electric Railway, not Including Operations of Railway Companies	10	2,912	14,856,068
Cars, Steam-Railroad, not Including Operations of Railroad Companies	108	45,121	325,680,157
Motorcycles and Parts	22	2,665	13,567,970
Bicycles and Parts	24	1,643	9,529,779
Wheelbarrows	11	228	1,454,581
Total	3,590	281,350	$2,508,654,870

The Public's and the Car-Builders' Attitude Toward Balloon Tires

By J. E. Hale[1]

Indiana Section Paper *Illustrated with* Photograph and Drawing

STATING that the adjustment records of the tire companies afford ample proof that under-inflation is one of the most flagrant forms of tire abuse, the author cites this to show that the public demand is to ride on tires having low inflation-pressure on account of the comfort secured thereby. Statistics obtained in 1922 show that endurance, economy of operation and comfort head the list of car attributes that the public desires most. It is claimed that these qualities are securable by using low-pressure air in tires or sufficiently large cross-section and special design.

An analysis of the opposition to balloon tires, the effect of balloon tires on acceleration and pick-up, an argument to show that the balloon tire is a distinct type, details of balloon-tire application to cars and rebound-checks as adjuncts to the use of balloon tires comprise the main divisions of the paper. Six specific conclusions are presented.

IN the paper entitled Shoeing a Car with Low-Pressure Air,[2] which I presented at the Semi-Annual Meeting of the Society, at Spring Lake, N. J., in June, 1923, the treatment of this subject was from a tire-maker's point of view. I reported my observations on what the tires would do for the car and how they would affect the operation of the car, made some predictions on their durability and cost and concluded by proposing a line-up of sizes with a recommendation for amounts of air pressure. This summarized the very extensive development work in which we had been engaged and was really a first presentation of the subject to the industry. Since then the matter has been given such wide publicity that not only the car-builders but a considerable proportion of the public have become acquainted with the possibility of riding on low-pressure air. All the car-builders have had sample sets of balloon tires for experimental purposes. Also, many private owners have had their cars changed-over and have been running on this new form of tire equipment for many months. It seems desirable at this time to review the reactions of these two groups and to see what conclusions can be drawn.

The primary motive underlying this movement was the belief that the motoring public would appreciate a type of tire that would permit it to use low-pressure air, in order that it might enjoy the greater personal comfort of much improved cushioning, the protection that soft tires give to the mechanism of the car and the improved traction that would result from greater tread contact. As a matter of fact, this demand for low-pressure tires has actually existed for a long time. The proof of this is that many people under-inflate their tires. The tire companies have ample evidence of this; their adjustment records show under-inflation to be of the most flagrant forms of tire abuse and, while undoubtedly many of the cases are due to negligence, it is well known that it is common practice for car-owners, who do not figure tire-mileage costs, to run deliberately at low inflation for the comfort and protection that they can secure.

Since disclosing the balloon tire and explaining that it is deliberately designed to use low-pressure air, the public has grasped the idea, and definite indications are noticed that it will take matters into its own hands and ride on low-pressure with its present equipment which, of course, is something we cannot authorize with the heavy, thick-wall construction. The important point is that the public wants the personal comfort, the protection of the car and the like that low pressure gives. Our problem is to produce the true low-pressure tire that we can stand back of.

Further evidence of the logic of this movement is given by the returns of the ballot taken by the National Automobile Chamber of Commerce in 1922, in which it sought "what the public wants" from 20,000 car-owners. In these returns, endurance, economy of operation and comfort head the list of the attributes the public desires most, and these are the things that we claim are had by the use of low-pressure air. The returns were reported as shown in Table 1.

TABLE 1—CAR ATTRIBUTES DESIRED MOST

	Per Cent
Endurance	15.0
Economy of Operation	14.0
Comfort	9.5
Price	9.5
Appearance	8.0
Service, Good Local Repair Shops	7.5
Hill-Climbing	7.0
Flexibility	6.5
Endorsements, Opinions of Other Owners	6.5
Specifications	6.0
Speed	5.5
Appointments	5.0
Total	100.0

One of the big problems that has always confronted the tire manufacturers is convincing the motoring public that it must inflate its tires properly to avoid premature failure due to under-inflation. The fight to maintain air pressures is so old, and has been carried on so persistently, that the motoring public has accepted proper inflation as one of the nuisances that are necessary to the use of the automobile and, in a general way, it understands some of the reasons. But few have raised the question as to designing tires that could be run at a much lower inflation-pressure. The solution of this problem was not evident to tire designers until the evolution in the tire industry had opened the way for the balloon tire. Now it seems so simple and logical that we naturally wonder why we did not think of it before. With the details worked out, the public grasped the idea instinctively and the reaction we get from individuals is indicated by the questions they ask, such

[1] M.S.A.E.—Manager of the development department, Firestone Tire & Rubber Co., Akron, Ohio.

[2] See The Journal, July, 1923, p. 41.

as "How does it affect the steering?" "Does it cut down the gasoline consumption?" "How much do they cost?" "What air pressure is used?" "Can I buy a set for my car?"

Realizing that a sizable portion of the public had discovered the attractive features of riding on low-pressure air, we felt well pleased with our efforts when we discovered the way to make riding on low pressure legitimate. The psychological reactions that we have encountered among the motor-car builders, however, have disclosed various points of view. Of course, the first reaction in most cases was that of curiosity, to learn as much as possible about the tires from personal observations on sample sets. Then, true to the responsibilities of their positions, each and every car-designer proceeded to search for objections to this new equipment; naturally, they found that the balloon tires, having some characteristics different from those of high-pressure pneumatics, could not be substituted without due consideration. They agree almost universally that the low-pressure tires give a better ride; in no case have I heard any contention that the tires do not do what we claim for them, yet the attitude toward them ranges all the way from actual adoption to direct opposition, with all kinds of intermediate opinions. So, the matter we are facing in satisfying the public on low air-pressures is to examine more closely into the apparent resistance toward the adoption of this type of tire. In a general way, it must be due to psychological, engineering or economic reasons.

Analysis of Balloon-Tire Opposition

So far as economic reasons are concerned, the monetary appropriations involved are not excessive, since they are confined to fender charges and details of brake and axle design to provide additional offset. As to engineering obstacles, I have not heard of anything insurmountable in this direction. Naturally, a new tire-equipment of this description could not be expected to fit the vehicles without some alterations or modifications; but I submit as proof that the objections cannot be serious the fact that, of the dozens of cars which have been changed-over, the owners have found them to be entirely satisfactory. Of course, in some cases the fenders were not wide enough with the new equipment and as a result mud would be spattered in an objectionable manner; but this is simply something for the car engineers to overcome by redesigning the fenders.

In a few cases, car designers have encountered front-wheel shimmy with cars fitted with balloon tires and for that reason have disapproved of this form of equipment. So far as I have been able to discover, this form of trouble almost never occurs at speeds below 60 m.p.h. A few cases of front-wheel shimmy have come to my attention on change-over jobs but in all cases the shop mechanics have been able to make some adjustments in the steering mechanism that eliminated it. On my own roadster car I can bring about front-wheel shimmy at any time by slacking-off a three-quarter turn on a certain nut in the steering linkage, thereby introducing a certain amount of play, but I can remove it simply by tightening this nut again.

The effort required for steering receives very prominent consideration, of course. A soft tire steers somewhat harder than a highly inflated tire, and this low-air-pressure project caused many people to make comparisons. Some steering-gear changes have already been made, and gears are available which give satisfactory results. We feel sure that this objection will disappear.

Effect on Acceleration

Another point that has come up in a few cases, and apparently has been registered as a primary objection, is that the acceleration in car performance is affected adversely by low-pressure tires. One can understand readily why the car-builder who has expended a large amount of time and effort in trying to excel in acceleration is reluctant to have any elements introduced in his equipment that will disturb the performance of the car, in this respect; but, so far as I have been able to determine, the low-pressure tires affect the engine performance only slightly. On a coasting test, as one senses the action of a car rolling downhill in ordinary driving, certainly no evidence of drag or sluggishness is present.

So far as fuel consumption is concerned, plenty of information is available to the effect that this is not affected adversely; in fact, evidence can be adduced that there is a slight increase in gasoline mileage when using the balloon tires. I have just completed a 1200-mile trip in my 4-year-old roadster that was equipped with balloon tires and pretty heavily loaded. I averaged 17 miles per gal. for the entire trip.

Predictions of serious accidents have been registered in case one of these thin-wall tires should blow-out on a vehicle running at high speed, particularly a front-wheel tire. So far, no trouble has been experienced from this source; surely, if the allegation were true, something would have happened long before this because a large number of these tires have been in service long enough to give actual experience along this line. The experiences that have relieved most completely the minds of those who were apprehensive in this regard are those of Cannonball Baker. He had a front tire go flat while running a touring car, 55 m.p.h. He reported that he noticed no particular difference in the performance of the car with the 7.30-in. balloon-tires, which he had on the car at the time, and similar occurrences that he had previously with the regular 33 x 5-in. high-pressure tires. In other words, there was nothing dangerous, the only reaction being a slight tendency for the car to draw to the flat-tire side. He had a tire go flat on a rear wheel while running 75 m.p.h. Inasmuch as he was attempting to make a record, he continued to run at high speed for 15 miles on the flat tire. Fig. 1, shows the condition of this tire after it was sent in for our inspection. The punishment was so severe that the rubber was actually all gummy from being devulcanized. But the important thing is that he was able to drive the car with this dish-rag-like appendage on the wheel. Incidentally, it is interesting to note the thorough-going way in which the company that built the touring car mentioned was able to investigate air-cushion tires by putting the car, so equipped, into the hands of a driver like Cannonball Baker. This course enabled the company to reach conclusions very quickly.

At the inception of this balloon-tire idea, we were rather of the opinion that we were developing a luxury tire which probably would be limited to application on cars of the more expensive type; but, as our work expanded and we began to get reactions from car-builders, it became apparent that the low-pressure air would be universally desirable. As a matter of fact, low-pressure air in tires offers a greater improvement comparatively in comfort and in protection to the vehicle in the case of moderate and low-priced cars.

Balloon Tires A Distinct Type

It should be understood definitely that what we term balloon tires, while they resemble the high-pressure

pneumatic tires, are sufficiently different in many of their details to constitute an entirely distinct type. The distinguishing features of a true balloon-tire are: a very thin carcass, narrow rim-fitting, air-pressure recommendations for actual use ranging from 20 to 35 lb. per sq. in., a small-diameter rim to accommodate standing diameters no greater than those used at present and special tread designs adapted to low-pressure tires. My opinion is that the present line of tires and rims cannot be converted into the true balloon-type by oversizing and splitting the difference in the number of plies used. A satisfactory series of tire sizes for the new type has been under development for practically a year and in the following text I report certain general observations on the application of it to motor cars. This is a problem having two aspects; that is, the application of balloon tires as original equipment and their use as a change-over equipment for cars now in service. Our judgment is that four section-sizes of tire are necessary to equip the various cars properly with tires and at the same time to allow the pressure recommendations of from 20 to 35 lb. per sq. in. In a general way, the choice of tire sizes to be applied to the various cars is shown in Table 2. We have found that the cars can be grouped according to their wheelbases much more logically than in any other way, because cars of approximately the same wheelbase are likely to be of about the same weight. Some wheelbases are omitted from Table 2. These are border-line cases for which the tire sizes must be chosen by careful consideration of the front and rear weights when the car is loaded.

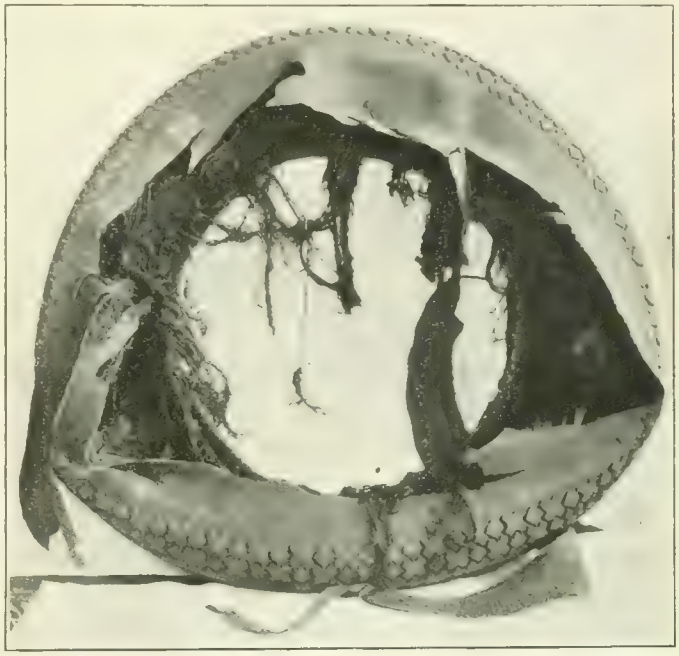


FIG. 1—A BALLOON TIRE THAT RAN FOR 15 MILES AT HIGH SPEED AFTER GOING FLAT AT A SPEED OF 75 M.P.H.

TABLE 2—BALLOON-TIRE SIZES SUITABLE FOR THE VARIOUS CARS

Balloon Tire, Actual Section, In.	High-Pressure Pneumatic-Tire Equivalent, In.	Maximum Load per Wheel, Lb.	Wheelbase Range of Cars for Each Size of Tire, In.
4.40	3.5	750	100 to 103
5.25	4.0	1,000	108 to 115
6.20	4.5	1,300	118 to 126
7.30	5.0	1,700	130 to 140

BALLOON-TIRE APPLICATION

When the factory fits balloon tires to new vehicles or does change-over work on existing cars, only two problems arise; first, how much to offset the rear wheels to clear the brake rigging so that the sidewall of the tire and the flange of the rim will clear; second, how to provide means for carrying the spare tire. Fig. 2 enables one to visualize the relative positions of the two types of equipment. In cases where the rear wheels do not have to be offset and the brake-drums are not too large in diameter, the wood wheels can be rebuilt using a steel-felloe wheel and a demountable rim that has been designed especially for these tires. These demountable rims are of the endless type and have a spring side-ring. Where wood wheels cannot be used because they cannot be offset sufficiently, either wire or disc wheels must be resorted to and for these cases the same type of rim has been worked out in such a manner as to be built into the disc or the wire wheel as the case may be.

We have found that fitting tires of the 4.40 and 5.25-in. size to cars in their respective classes, is a fairly straightforward proposition, the fender and the brake-drum clearances being naturally sufficient to accommodate the tire change without any complications. The

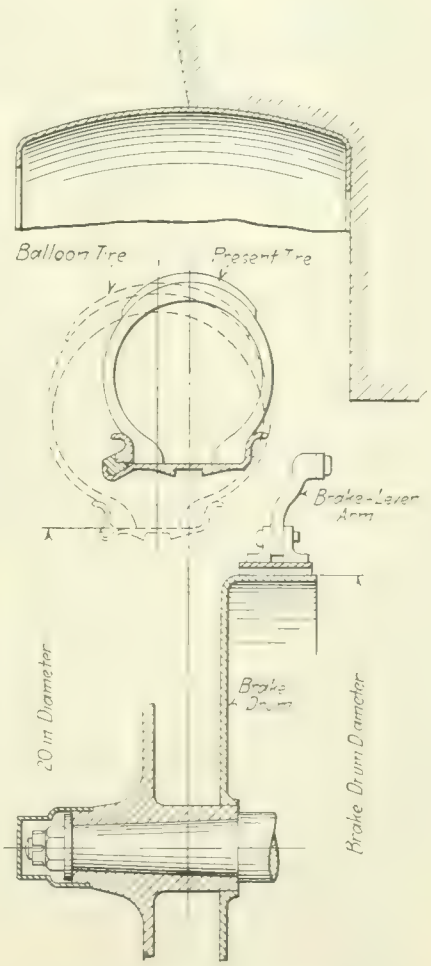


FIG. 2—RELATIVE POSITIONS OF BALLOON AND PNEUMATIC TIRES AS APPLIED TO AN ORDINARY WHEEL

builders of cars in these classes could adopt the balloon tire with little or no change in their chassis design, so far as these clearances are concerned.

In applying the 6.20-in. balloon-tire as a substitute for the 4.50-in. size on cars of 118 to 126-in. wheelbase, in most cases the rear wheels must be offset by amounts varying from $\frac{1}{2}$ to $\frac{3}{4}$ in. so that the sidewall of the tire or the flange of the rim will clear the brake-lever arm properly. In practically all cases the fenders are wide enough to cover the tires properly against mud-throwing.

The 7.30-in. tires replace the 33 x 5-in. size and are practically identical in standing diameter; so, the fender clearance is satisfactory. However, the brake-drum diameter of these large cars is sufficiently great that brake-mechanism interference calls for a greater offset of the tire for proper clearance, $\frac{3}{4}$ in. or more; so, the sidewall of the tire in some cases is rather near the outer fender line and this, of course, would account for mud-slinging. Car-builders naturally are reluctant to narrow the wheel housing because it cuts into the seat space; as a result, the resistance on this point is rather difficult to handle unless there is a willingness to increase the gage of the rear wheels to make up the deficiency. Reports have been received that the turning-radius of the steering-wheels has been reduced slightly with this tire in some cases.

Rebound Checks

In my former paper[1] I mentioned the desirability of using shock-absorbers or spring-rebound checks and predicted a disappointment with balloon tires without these instruments. I want to emphasize now even more strongly that some devices of this sort are necessary. The low-air-pressure tires will take care of the pavement irregularities splendidly but depressions in and humps on the general road level, that naturally are beyond the capability of the tire to care for and that call on the spring action seem to produce excessive rebound. I have found it of very great advantage to keep the spring leaves well oiled.

Discrimination must be used in choosing a type of rebound check. We have had cases where the applications are very unsatisfactory. The rebound seemed to be over-checked to such a degree that the riding was extremely choppy and, in spite of all adjustments, the condition could not be cured. On the other hand, the same rebound check gave very satisfactory results when applied to another car. This leads me to conclude that there is a very complex situation in which the spring characteristics play an important part.

Balloon-Tire Usage

It is nearly a year now since balloon tires have been under experimental observation and the major development work is completed. Naturally, some details will require modification and different treatment, but we feel that the automobile industry should consider this form of tire equipment now in its hands. It is for that industry to decide what shall be done with it. We know of some disadvantages in the balloon tires; for instance, they will suffer from under-inflation the same as the high-pressure tires do. Already, we have had a case in which an owner should have run with an air-pressure of 30 lb. per sq. in. but used a pressure of 20 lb. per sq. in. As a result, the tires failed prematurely. We find that in many cases individuals think that it will be possible to use pressures much lower than those we really contemplate.

Front-wheel alignment must receive more attention on cars equipped with the balloon tires. Premature tread-wear because of misalignment is common; the low-pressure tires are much more sensitive to this form of abuse than are the high-pressure tires. Our whole experience leads to the following conclusions:

(1) Unquestionably, the public will ride on low-pressure air

(2) The tire companies must meet the situation by designing and marketing tires that can be used with low-pressure air

(3) The public demand for balloon tires unquestionably will be so great that a large number of existing cars will be changed-over to use them

(4) The public will pay more for balloon-tire equipment because it looks better, rides better, brakes better and saves the car

(5) As soon as builders have learned what balloon tires will do for a car, they will be able to use lighter design and thereby save money

(6) The January, 1924, automobile show will include many cars equipped with balloon tires

THE DISCUSSION

QUESTION:—Is the name "Balloon Tire" appropriate? Why not use "Comfort Tire"?

J. E. HALE:—I did not like the name "Balloon Tire" and our company, also, hoped to get a more dignified name such at "Air-Cushion Tire." But everybody seems to say "Balloon Tire" and we cannot prevent it.

W. G. WALL:—Does the eventual fatigue of rubber have a large bearing on the life of the tire, or does the life depend on the fabric? By testing the rubber and the fabric in a machine, can definite statistics be obtained in regard to just the number of vibrations they will withstand?

MR. HALE:—I cannot give a definite answer as to the resistance to flexing of rubber that is not reinforced with fabric. My impression is that the ability of good-quality rubber to flex repeatedly is so great that it will continue to function in that way as long as the rubber is in good condition. We know that rubber, under stress, ages and becomes hard more rapidly than rubber not under stress. However, the cotton is the foundation of the tire. The rubber part will outlast the cotton part. The tire that wears out normally wears its tread off. We could increase the life of the tire by putting more tread on. We try, however, to build a balanced tire..

We recognize about 50 to 60 different types of tire failure. Flexing weakens the cotton, causing it to fray-out. Much of that action is in the side-wall sections of the tire. Obstacles, such as sharp sticks and glass often cut or pierce the tread rubber and get down into the cotton. That lets in water and dirt and the fabric begins to disintegrate slowly.

MR. WALL:—In these large tires a certain greater surface is being subjected to friction on the road due to the difference in speed of the different portions of the tire. Does that have a greater detrimental effect than on the tire that has a higher pressure?

MR. HALE:—The difference in the rolling speed of different portions of the tread of the tire manifests itself in a slight lack of uniformity of tread wear. It is customary to mount what we call a continuous "riding strip" around the middle of the tire. This strip wears less than the row of non-skid buttons on either side. However, this effect is not necessarily detrimental to the life of the tire.

This difference in the surface speed of the different portions of the tread undoubtedly has a desirable effect in improving the braking and traction characteristics of the tire, particularly on wet pavement, since the displacement action of the non-skid buttons produces a squeegee effect tending to wipe the pavement dry, thereby increasing the coefficient of friction.

MR. WALL:—Although more of the surface of these tires is on the ground, do we really have a better braking effect, due to the fact that the tire will come into contact with more obstacles than if it had only a small contact area? Is not the balloon tire more difficult to steer than the ordinary tire?

MR. HALE:—With any soft tire, it is, of course, more difficult to steer than with a highly inflated tire. This is the natural consequence of increasing the area of contact by 100 per cent.

T. VOORHEES:—Is a smaller wheel necessary on all cars equipped with balloon tires?

MR. HALE:—Consider a 33 x 5-in. tire. The rim diameter is 23 in. A 7.30-in. balloon tire is made as a substitute for this 33 x 5-in. size and, since this has a larger section, it is obvious that the wheel must be smaller. We do not want to increase the standing diameter of tires.

L. R. SMITH:—What is the difference in front-axle clearance with a flat tire?

MR. HALE:—A 5-in. tire drops, when becoming flat, 3.70 in. as compared with 4.75 in. for the corresponding balloon tire.

T. P. CHASE:—What is the effect of maximum braking as regards torsional stresses on the carcass?

MR. HALE:—Considering the tension in the cords, the increase is negligible compared to the air-pressure stresses. Rear tires wear out more quickly than front ones because they have from 30 to 60 per cent more load on them.

J. H. HUNT:—What changes can be made in steering to eliminate "shimmy" at the higher speeds?

MR. HALE:—When I first experimented with balloon tires I read the literature on "front-wheel shimmy"; but the more I read, the more perplexed I became, I have given up the solution of the problem. Much of the trouble lies in the steering-gear. We have had Ford cars equipped with balloon tires that would shimmy excessively at 15 m.p.h.; but when the back-lash was eliminated they would be all right. Having steering-wheels too free has a tendency to make a car "shimmy."

QUESTION:—How does the balloon tire wear in deep ruts and over rough spots?

MR. HALE:—A tire that has been run 15,000 to 18,000 miles will be worn but will have no cuts. Because the tire is soft and does not have such intense pressure back of it, it does not fight the road; it simply folds itself over. Running the tires against curbs does not injure the tires. One of the great troubles with most tires is the matter of tread separation. We have not had a single case of tread separation with balloon tires. While we have not had a winter's experience with these tires, I am sure that side-wall troubles will be negligible.

It would be foolish for me to argue that balloon tires will not puncture, but my experience indicates that the puncture trouble will not be excessive. Some of those who have had puncture troubles with balloon tires were simply unlucky. I have been driving almost a year and have not had a puncture yet. Mr. Putnam, of the Detroit Pressed Steel Co., drove 21,000 miles; he had three punctures.

MR. HUNT:—What happens to a balloon tire on a narrow country roads that compels driving in ruts?

MR. HALE:—It is not necessary to pay any attention to the ruts; drive right over them.

QUESTION:—What increase in mileage can be expected with balloon tires?

MR. HALE:—I cannot answer, because the balloon tires have not traveled far enough as yet.

CHARLES S. CRAWFORD:—Regardless of what an engineer thinks about the objections to balloon tires, his opinion will be over-ridden by the demand of the general public. I believe that the car-owner wants this kind of a tire, primarily on account of the improved riding qualities. We might as well pave the way for its use. The objection most talked of seems to have been hard steering. We have a certain standard of steering with conventional tires and a certain steering-gear ratio. This standard can be equalled with balloon tires by changing the ratio of the steering-gear. Frequently we receive complaints from customers of a car steering too easily, but the same car in the hands of another person was too stiff. In my opinion, the steering should be unusually easy and with this condition stiffer steering can be obtained merely by increasing the pressure on the ball-and-socket joints in the steering mechanism.

J. J. COLE:—In my opinion, there is the same difference in favor of balloon tires as compared with regular pneumatic tires as there is between solid and regular pneumatic tires.

R. H. HASSLER:—The experience of our organization with balloon tires has been limited to a few cars, but it shows very clearly the advantages of a two-way shock-absorber in stopping the peculiar "jiggly" action of these tires at the lower car speeds, or what Mr. Hale describes as a "choppy" action. We found that such a restraining device, adjusted to a low pressure, would overcome more completely this choppy action than when adjusted to a higher pressure. For example, cord tires would require a shock-absorber adjustment of 45 or 50 lb. per sq. in. to give the best riding qualities, while balloon tires on the same car would give best results at a shock-absorber pressure of only 30 lb. per sq. in. The two-way restraining-device would, in all cases, give far better results than could be obtained by any adjustment of the one-way device from very light to very heavy, even trying the latter at very high pulls of from 150 to 200 lb. In other words, very little shock-absorber control is needed to stop this peculiar action of the balloon tires, but it must be applied constantly, both up and down. When applied and adjusted properly in this manner, the results are very gratifying.

QUESTION:—Our experience with these tires is that when coming into contact with the ground, they roll-up and then snap out, making a great noise. What has been Mr. Hale's experience is this regard?

MR. HALE:—Some tire-treads are designed so that they have suction pockets, I have not had any experience with the noise mentioned.

The Nature of Matter

By H. B. Lemon[1]

The theories and conceptions presented include valency, the photoelectric effect, the Edison effect, ionization, mass measurements, configurations of electrons for different substances, the Rutherford idea, dimensional conceptions, electrons and the atomic nucleus.

LEST you labor under a misapprehension, let me say at the outset that neither I nor anyone else, so far as I am aware, knows anything about this subject compared to what there is to learn. We have just begun to scratch the surface, and certainly no one realizes better than the physicist, or the chemist, how little we know.

I do not expect, nor have I been asked to make a contribution to your knowledge of fuels. I hardly expect that you will find any significant facts in my remarks that will help you in your own individual problems, other than the general fact that the more we know about the background of science and of nature in general, the more power and control we shall have in any special field. It is true sometimes that methods in wholly different fields become suggestive. I wish to correct a general impression that the ideas of a physicist and a chemist on the nature of matter are subject to continual revision and are never twice alike; and I have organized the remarks that I have to make mainly toward that end.

Scientific men lay great emphasis on the changes and modifications of points of view that are necessitated by the discovery of new material; and, of course, the discovery of new materials, the unearthing of new facts, is the essential work of the experimenter. The non-technical public, not having the background, often considers as revolutionary changes and discussions that really amount to a veritable tempest in a teapot. During the last quarter of a century there have arisen in the world a new physics and a new chemistry, not like a phoenix from the ashes of a conflagration, but rather like an edifice that is built solidly and securely on the foundations of the past.

In our high-school days, most of us were taught that an atom is the ultimate particle into which matter can be divided, that if we took a piece of chalk we could go on dividing it indefinitely until we came finally to a place where further division altered the properties of the thing we were dividing; in other words, we came then to the molecule, and a division of the molecule left us with component parts that were not like the original, with component parts that were atoms. Of course, that was purely an academic point of view; no one ever succeeded in dividing a substance until an atom was reached; it was only an abstract idea. We were taught that about 80 so-called different elements, by combination, composed all of the substances with which we were familiar. This picture is still before us, but we have now about 92 elements.

Mendeleef, the distinguished Russian chemist, in 1869 first formulated his periodic table of the elements, which most of us can recall from high-school days and which is still an essential part of the equipment of every scientific laboratory. The fact that chemical atoms are not all different was first discovered by Newlands and formulated more directly by Mendeleef a few years later.

If we take almost any atomic or molecular property and form a graph, arranging the chemical elements in the order of weight as ordinates against the property that we select, such as for example the absolute temperature of fusion, as abscissas, we get a curve that we see at once has periodicity. Or if the atomic volumes are plotted against the atomic weights, we have a curve that has successive peaks and, if we recall the chemistry of our school days, we may remember that lithium, sodium, potassium, rubidium and caesium are chemically similar elements and we notice that they occupy corresponding positions on the curve. These facts of course are very old and well known.[2]

If the chemical elements are put down in the order of their increasing atomic weights, after we write down seven of them, and seven ever was a magic number, the eighth has to be written under the first, the ninth under the second and the tenth under the third; at least, if we do that we shall have in vertical columns elements that have similar chemical properties. This is a very early shadow cast ahead by the portentous discoveries that lie just beyond the horizon. If these ultimate things, the atoms, are related, then there must be something more fundamental than them by which, or in terms of which, they are related. At any rate, there must be a mechanism that relates them, a mechanism that we think should be more fundamental than the things that the mechanism relates.

Michael Faraday, in 1833, formulated some facts that were equally significant, in the laws of electrolysis, and it is important to realize that the modern points of view are nothing but the developments of his early discoveries. Faraday, studying the conduction of electricity through electrolytes, or solutions of substances that became conductors of electricity, formulated three laws. The first

[1] Professor of Physics, University of Chicago, Chicago.

[2] Compare Richtmyer and K. K. Darrow, p. 24.

of these is that the quantity of the substances decomposed is proportional to the quantity of electricity that goes through the solution. The second states that if different elements, such as carbon, copper or zinc, are involved in the electrolyte, the weights deposited out of the solution by equal quantities of electricity are strictly proportional to the relative weights of the substances themselves. In other words, if we have a substance that is twice as heavy as another, and both are in the electrolyte, the same quantity of electricity passing through the two solutions in series will deposit out of the solution that contains the heavier elements exactly twice what will be deposited out of the lighter element, provided the elements have the same chemical characteristics; that is, provided they both combine with hydrogen in the same fashion. But if we have one element that combines with hydrogen differently from another, in the sense that we associate two atoms of it with hydrogen where we associate one atom of the other with hydrogen, then, according to the third law, the weights deposited will not be proportional to the atomic weights alone, but will be proportional to the atomic weights divided by the valency. These laws are capable of but one interpretation, which identifies a definite quantity of electricity with an atom of matter. You see it is entirely immaterial, except for the valency integer, what atom of matter we select.

Valency

Let me give an example of what we mean by this idea of valency. If 200 people were carried from one locality to another by 50 automobiles, we should infer, if the automobiles were each filled equally, that they were four-passenger cars. In other words, the substance carried and the substance carrying would be related by the figure four which, in this case, would correspond to the valency. If, on the other hand, the people were observed to travel in 28 automobiles, we should be compelled to conclude that they traveled in seven-passenger cars and that four of them traveled in some other way. There would be no distinction whatsoever between the makes of automobile; the sole distinction would be in the carrying capacity. Thus Faraday discovered in all the various brands of element one essential property in which they were all alike.

These important contributions from the past constitute the foundation of our modern point of view. If atoms are related and are not all different, there must be something relating them. From Faraday's experiments, we suspect that this something is electrical in its nature. The twentieth century, then, found the stage set and ready for the discoveries to be ushered in. The most significant of these was the photoelectric effect discovered by Hallwachs in 1908, but not interpreted in its full significance until a little later.

Photoelectric Effect

To show the photoelectric effect, an electroscope is placed in front of a stereopticon, which projects it upon a screen. The electroscope consists of a metal plate having a bit of gold-leaf hung from it in such fashion that the gold-leaf hangs parallel to the plate being attached to the upper end. When a charge of electricity is put upon the leaf, the leaf projects because of the electrification on the plate and the rod on the leaf. Hallwachs observed that if a zinc plate were illuminated with ultra-violet light, any charge that the electroscope carried leaked away. When the plate is charged, one can see that there is, on the whole, no leakage; but if a mercury-arc light in a quartz tube is used, the illumination causes an immediate falling of the leaf. It was observed that this effect occurred only when the plate was negatively charged. The interpretation was, that if there is a negative charge on the zinc plate and the charge leaks off, it might be ascribed perhaps to the air or to the effects that the air has; however, after many months of patient investigation, it was found that the effect occurred in the highest vacuum that could be produced, that it was the same for different metals other than zinc and that it was purely a unidirectional effect. If the plate were positively charged, the effect did not occur. There could be only one interpretation of that. If the leaf is discharged, the electrification gets away; the electrification in the negative case must be negative electrification that gets away. There must be an emission of negative electrification under the action of the ultra-violet light. If, on the other hand, the plate were positively charged, it would appear that positive electrification does not do this. As a matter of fact, if the plate originally had no charge whatsoever but was merely exposed to the light, it was found to acquire a small positive charge. In other words, the action of the light was interpreted as releasing negative electrification. That release of negative electrification cannot go on indefinitely because, if negative electricity escapes from a neutral plate, it leaves the plate positive and, by the time the positive electricity has accumulated sufficiently, it has enough attraction for the negative electricity that remains to hold it to the plate, irrespective of the action of the light. So, the positive charge acquired by a metal surface under the action of ultra-violet light is conclusive evidence of the emission of negative electrification from the plate.

Another conclusive proof that there was negative electrification escaping was that other plates in the vicinity and in the way of this discharge were found to acquire a negative charge. Moreover, the properties were found to be wholly independent of the metals involved, except that the different wave-lengths of light sometimes were necessary to produce the charge. It could not always be produced by light of the same wave-length. As a matter of fact, it has been discovered recently that practically all the metals up to sodium show the photoelectric effect and that, with metals of the third series, particularly sodium and potassium, there is no need of ultra-violet light. Ordinary light, even red light, is capable of detaching negative electrification from sodium and potassium. That is the first significant discovery.

Edison Effect

The second discovery is attributed to Edison, who made it in connection with his experiments on the incandescent lamp. If an incandescent filament in a vacuum is connected through a battery and current flows through the filament so that the latter is heated to a sufficiently high temperature, we find that an insulated electrode in the side wall of the bulb connected through a galvanometer will acquire a charge and that current will flow through the galvanometer.

This can be demonstrated by using an ordinary incandescent-light bulb that has had its tip broken off. A blow-pipe is placed on the side of the bulb and a small hole is blown which is then filled up with sealing glass containing a platinum electrode. If the bulb is then sealed back to the vacuum pump and reexhausted, it will light in the usual fashion. When a connection is made with the positive terminal the current comes into one

[illegible] wire goes from the other terminal to a galvanometer and the galvanometer is connected with the [illegible] electrode. There is no electrical connection between the galvanometer and the lamp in the sense that any current can go through the galvanometer, because the wire is insulated from the filament by at least 1 in. of vacuum. A vacuum is as high an insulation as can possibly be attained. Yet, if the excitation of the lamp is increased sufficiently current will flow and it is no small amount of current at that. Of course, this effect is the fundamental effect of the vacuum tube, which has become so important an adjunct of our modern civilization.

Here we have conditions that are essentially different from the photoelectric effect; yet they are equally significant. An ammeter in a circuit will show the current passing through the lamp. The sense of the deflection of the galvanometer shows that negative electrification is coming out of the wire, and that tallies perfectly with the photoelectric effect. Since the wire is negatively charged, compared with the other end of the galvanometer, if there is free negative-electrification in the space, it will be repelled from the filament to the plate. So, negative electrification travels across the gap, just as was described for the photoelectric effect.

Lenard and Lodge and Thomson and a number of others have studied the details of these two effects, and the interpretation was not long in being made. The emission was undoubtedly electrification. It consisted, it was found, of discrete particles, and these particles had identical properties irrespective of their source. In other words, whether they came from a carbon filament or a tungsten filament or a zinc plate or a copper wire, they were indistinguishable from one another; things were discovered that came from atoms, which were smaller than atoms and which were the same from all atoms. This, then, is the mechanism by which the atoms were to be related.

These particles, themselves invisible, make themselves visible in a variety of ways. If they impinge upon certain minerals they cause fluorescence. If, when sufficiently concentrated, they impinge upon a bit of platinum foil, they raise the temperature of the platinum to above the melting point. In other words, they possess mass, because they possess kinetic energy, and are capable, upon impact, of being converted into heat. They affect a photographic plate, they impart a negative charge to anything that comes into their path and they are capable, as one might suspect, of causing even mechanical effects.

When these particles are present in ordinary air they render it conductive. This can be demonstrated by replacing the electroscope I described above with another that is practically the same, but its outside terminal, or the case, is connected with the lower wire and the gold-leaf is connected with the upper wire; a third wire is connected to a gas-pipe that runs into the earth. The leaf is connected with the upper wire, and, by touching the upper wire, the electroscope becomes charged. The charge is maintained and the leaf is practically motionless although the wire is passing out through the air; in other words the air is non-conductive. But the air can be made conductive by lighting a match and passing it beneath the wire. As the match flame is passed between the wire, a deflection of the gold-leaf is noticeable. If the match flame is held under the wire, the deflection increases and the leaf is completely discharged; in other words, gases from an ordinary flame appear to render the atmosphere conductive. It must contain these particles of electricity. This effect takes place irrespective of whether the leaf is positively or negatively charged.

If the two wires are connected to two condenser-plates, and if a Bunsen-burner flame is held between the two plates, the leaf collapses instantly; in other words, we produce from a flame a much larger amount of electrification, as we should expect. If the leaf is charged and another pair of condenser-plates, placed a little closer together and one of them polished, are illuminated with ultra-violet light, the leaf also collapses. This may appear to be like the effect obtainable with a zinc plate but it is not, because the ultra-violet light does not necessarily have to shine on the plates now but merely on the air between them. The effect is not nearly so vigorous in the case of ultra-violet light. The moment the light is extinguished the effect stops.

A variety of other causes render ordinary gases conductive. If a small X-ray bulb is excited, the passage of the X-rays through the atmosphere also will cause a collapse of the leaf and that effect persists for 2 or 3 sec. after the rays are turned off; in other words, the electrification, or whatever it may be, of the air is much more vigorous than with ultra-violet light. A tube of radio-active material in the vicinity would cause this conductivity also.

Ionization and Mass Measurements

The mechanism here is precisely that of the zinc plate. The atoms of ordinary oxygen and hydrogen in the air, under the action of these various radiations, such as the chemical reaction of the high temperature and the flame, the ultra-violet light and the X-rays, have negative electricity detached from them; we have a group of atoms ionized, as we say. This means that a negative electrification is perhaps detached from one, which leaves it positively charged. In the presence of other atoms, this electrical particle does not remain isolated but attaches itself at once to another atom, which then becomes negatively charged; so, we have charges of atomic size. We have charged atoms and molecules of either size and, under the influence of the plates, one of which is positively and one negatively charged, the negatively charged atoms moving one way, the positively charged atoms moving the other way; and we have Benjamin Franklin's old two-fluid theory of electricity in action, that of positive ionization and negative ionization traveling in opposite directions.

These experiments show that not only metals but ordinary materials can be ionized and can be charged electrically. When ordinary atoms are charged we call those charged atoms ions. It is a term we have taken over from the old idea of conductivity in solutions. But we have conductivity in gases now. The sizes of the masses of these electrical particles have been measured, because the particles were found to be capable of deflection in a magnetic field, as one would expect electrical charges to be; in other words, they can be weighed by the centrifugal forces that are involved as they are swung round with magnets, in the same way that one can determine the mass of a stone by swinging it round one's head and estimating the pull.

There is a zinc-sulphide screen on the vertical plate in this discharge-tube which is fluorescent under the action of the negatively electrified particles, or electrons, as they are called. There is a small slit in a vein of mica immediately over the lower plate so as to make a narrow beam and, as the particles shoot upward, they leave a luminous trail on the screen. A bar magnet is capable

of deflecting the beam. If such a magnet is put behind the tube, the beam can be bent away from the screen, or back into the screen, because it follows the magnet around.

Without going into the mathematical details, the masses, the velocities and the charges on these particles can be measured from this simple experiment. The masses are found to be inconceivably minute; they amount to 10^{-27} grams. The smallest chemical atom that we know of, the atom of hydrogen, has a mass of 10^{-24} grams. So the masses of these particles are, as a matter of fact, 1/1845 that of the lightest atom. The velocities at which they travel in such a tube are prodigious, running from 10,000 to 100,000 miles per sec. The charge they carry is so small that it would take the entire population of such a city as Chicago, with every individual counting night and day for 2500 years, to count the number of them that pass through an incandescent lamp filament in 1 sec.

It appears that we are talking in large terms. We are. I assure you that in these phenomena one finds something of awe which corresponds to the order of the numbers involved. The strangest part of it all to me is that such insignificant chunks of carbon and nitrogen as ourselves are able to find out anything about these things. It is fully as astounding, more astounding in some ways, than our knowledge of the nebulæ that are so inconceivably far away. It makes one think that perhaps size after all is such a relative matter that it is almost a delusion.

Configurations of Electrons

If we have negative electrons coming from or composing all kinds of matter, how are we to think of their entering into composition? An analogy, which I wish to emphasize as nothing but an analogy, was suggested first by Sir J. J. Thomson, and experimentally improved later by Prof. R. R. Ramsay of the University of Indiana.

If some small steel balls are floated on a vessel of mercury beneath which is a magnet, the steel balls will be magnetized by induction from the magnet and consequently will be attracted through the region immediately above it, being free to float around. On the other hand, being magnetized alike, they will not get too close together because like kinds of magnetisation repel each other; in other words, these steel balls will be maintained in a certain region in the surface of the mercury by the attraction of the magnet beneath, but will be kept apart by virtue of their mutual repulsion. Thomson thought of an atom as some such sort of thing, originally a uniform sphere of positive electrification, which was merely another way of formulating his ignorance of what it was; something to hold these negative electrons together so that they would not fly to the uttermost corners of space by virtue of their own mutual repulsion. Understand, this is merely an analogy, but it is one of the most striking analogies in the history of science.

Such a vessel of mercury can be illuminated with the stereopticon arc and projected on a screen. If steel balls of 1/16-in. size, such as are used for ball bearings, are floated on the mercury, they will at once be attracted and be fairly mobile when the magnetic field is on. Two of the balls will arrange themselves, very naturally, at the opposite ends of a straight line. If a third comes in, it will form an equilateral triangle; a fourth will form a rectangle, usually a square; a fifth apparently causes a condition of uncertainty. There may be, in this last case, an attempt at an irregular pentagon, but with slight assistance one ball will go to the center and thus a square will be produced with a ball in the middle. That condition is not so stable as the other, and the irregular pentagon tends to recur. But with six balls there is no doubt; one will go to the center, and if a person should try to make a regular hexagon of that number of balls, he would not succeed.

As the number of balls is increased, the result is analogous to an atom being built up from its constituent electrons. But an atom would not stay still like that and let one look at it. If the magnetic field is removed, the result is that the parting of the balls at the center will cease and they will coagulate into a single mass. If an electrical current, a radial current, is sent through that configuration through the mercury, from an electrode at the center to a ring electrode on the outside, these steel-ball magnets will move in the electrical field and begin a perambulation around the central electrode, showing an analogy to the way in which electrons rotate, but the rotations are so slow that they really are not worth mentioning.[3]

The Rutherford Idea

More recent work has abundantly confirmed the ideas suggested in Thomson's earlier theory, but we must think of these atoms in three-dimensional configuration with their electrons in successive layers, such as might be likened to the successive skins of an onion, not at rest but moving with very great velocity and, from the point of view of Rutherford and some of the later investigators, we are led to certain convictions about the nature of the central nucleus that binds the thing together.

There is a central nucleus. Experiments on particles that are shot out from radioactive substances, scattering experiments performed first by Rutherford and Geiger, show conclusively that the central force binding these elements or electrons together was confined to a region in the interior of the atom infinitesimally small compared with the dimensions of the electron that formed its constituent parts. In other words, we have what is known as the Rutherford atom, in which we have the central nucleus of dimensions 10^{-15} cm. and electrons of dimensions 10^{-12} cm., whereas we have known for some time that the atom as a whole is of the order of 10^{-8} cm. (1 cm. = 0.3937 in.). The atom itself is only a few hundred millionths of a centimeter, but the electrons that fill the space individually are 10,000 times as small as the space they occupy. So, the picture of having a few grains of sand flying around in the interior of a cathedral is analogous to our picture of the atom; and the nucleus that holds these few grains of sand is 1000 times smaller than the electrons themselves.

Dimensional Conceptions

With regard to the size of the atoms, we rely for this number on data that are, on the whole, just as certain as ordinary data in astronomy, which tell us of the sizes, masses, distances and objects in the solar system. They are checked from half a dozen different points of view. With regard to the size of the electrons, we are not so certain, yet it is almost inconceivable that this dimension will be altered appreciably with respect to the other. In other words, we are not likely to revise our opinion of the relative size of the electrons and the space that they fill inside this little solar system, which is the atom. With regard to the size and the nature of the nucleus, we do not know very much as yet, but new facts are appearing in almost every number of the *Philosophical Magazine*,

[3] For details of these arrangements, see *Physical Review*, vol. 34, pp. 242 and 243.

miles; further, in order that he shall all his materials proportionately enlarged. With such an increase in the size of his world, his atoms would be brought within the ken of us who remain as formerly; because its size is of the order of 0.001 in. It would be something more than 0.001 in., a quantity easily measurable under a microscope. The electron would be inside this space, which is a 4-in. sphere representing the atom, and in which we would see nothing else; yet no other atom could come into this 4-in. sphere of space because of the tremendous influence that the electron has over the space. That 4-in. sphere of space is like a solid particle; under ordinary conditions it is not to be penetrated by another space just like it. The electron goes around so fast in it that we can say it is everywhere at once and keeps everything else out. The nucleus of the atom, however, would be utterly beyond our ken still, because it would amount to less than 0.0000001 in. in diameter.

Let the scale expand and become a little larger; we must get at the size of that nucleus. Let the 4-in. atom now become as large as the earth and, still expanding, fill the entire orbit of the earth, so that our atom is now a space 186,000,000 miles in diameter. The orbit of the earth round the sun is now our atom. In that orbit a body the size of the earth can represent the electron. The electron has swelled considerably, you see, by the enlargement. The nucleus at the center is not like our sun, an object prodigiously large compared to the earth, but a tiny sphere 4 miles in diameter.

In terms of this imaginarily enlarged atom, how large has our imaginary man grown to be? We started out with a man who reached from the earth to the moon. On this scale, the man would have a height greater than 10^{10} miles. A light-ray travels less than 10^{12} miles in a year. It was measured first by Professor Michaelson as having a velocity of 186,000 miles per sec. A beam of light is the swiftest means of communication that we have. It can travel eight times round the earth in 1 sec., to the moon in 0.18 sec., to the sun in 8 min. and across the entire solar system to the orbit of Neptune in 8 hr., traveling in an entire year 10^{7} miles, that is, only 1/10 of the entire abscissa. In other words, the height of the man on this scale would be greater than 10^{4}; that is, between 10,000 and 100,000 light-years. Now 100,000 light-years would more than bridge the entire known universe of stars. So we come to conclusions that are stimulating to reflection, even though the figures are more or less amusing. We look out into space and we look into the interior of things that are about equally far apart. It is still as absurd as it was in the time of Copernicus to assume that we are placed at the center of this pageant. I myself prefer the conviction that its boundaries are set merely by our own human limitations. It is curious that we see about the same number of powers of 10 each way, because it shows that, on the whole, we have been about as active in one direction as in the other.

THE DISCUSSION

DR. H. C. DICKINSON:—Subjects that members of the Society have been very much interested in for the last 2 or 3 years have very close connection with some of the things Professor Lemon has spoken of. I refer particularly to the phenomena that occur in the combustion of fuels. We have learned some very important facts. Thomas Midgley, Jr., has talked to us many times about the very interesting features of this performance. I believe we shall not be able to answer all the questions that Mr. Midgley's results have raised until we apply ourselves much more fully to some of the things of which Professor Lemon has told us.

H. L. HORNING:—I experienced great satisfaction in witnessing Professor Lemon's demonstration of the Edison effect, particularly because, in 1898, I recognized the same effect in the laboratory and utilized it in dissecting the waves sent off from a static discharge. We were condensing an electric charge in a number of Leyden jars connected with a static machine, and were using this discharge to produce the yellow line of sodium in the spectrum. I had to pass over to the other side of the laboratory and saw an incandescent-light bulb lying on a table. Every time the spark jumped, the bulb lit with a phosphorescent glow. Realizing that this was due to radiation, I picked up the bulb and walked away with it. Then I thought that possibly if I put a little tinfoil on the tip I might magnify the effect. I was able that year to send a message something like 120 ft. through the walls of the institution. I shall always look upon that as one of the great moments of my life because, unknown to me, I was merely sending a wireless message and receiving it by the very methods that are effective today. This was a great lesson also, for while the world eventually reaps its reward from new ideas, the great benefits come from the successful efforts of the men who bring the ideas to practical usefulness.

I was particularly interested also at that time in the decomposition of water and made another discovery that I never used. When I put two electrodes under water and decomposed it with the electrodes very close to one another, there was very rapid decomposition at the tip; as a matter of fact, the oxygen and the hydrogen were intermingled. An intermittent process was set up by which oxygen and hydrogen were suddenly formed and the current was interrupted. As Professor Lemon has said, the electrons of which the current is composed have inertia; they also have weight; therefore, they would not stop. They jumped across the gap in the form of an electric spark and started the process of combustion; the oxygen and hydrogen united again, forming water, and then decomposed again into oxygen and hydrogen. The operation repeated itself with great rapidity. It made a beautiful effect under the water, because it showed a little arc-light that we were all satisfied was fire under water. We understood it perfectly but did not use it. A year later I found that Professor Wehnelt, of Germany, had used that as an interrupter for the X-ray machines that were being developed at that time. I think it is used even to this day.

I was interested in Professor Lemon's discussion of photoelectricity, as I have always recognized that effect inside the internal-combustion engine. I found that a zinc plate is charged when bombarded by the radiations of the explosion.

P. S. TICE:—Has Professor Lemon attempted to shed a little light on some of our fuel problems along the lines of his paper?

PROF. H. B. LEMON:—No. We are not an engineering laboratory, and the only opportunity that we have at present for investigating internal-combustion engines is on one very small four-cylinder, four-cycle marine engine that is used in one of our elementary courses. I am giving an advanced laboratory course in heat, and we certainly shall become interested in some of the more modern problems of experimental thermodynamics. I shall welcome suggestions regarding the fuel problems that you are endeavoring to solve.

MR. TICE:—Thomas Midgley, Jr., talks about "hitting this animal on the head and breaking it into parts." Prof. C. A. Norman tells us about "shaking the snake apart." Can an analogy be given? In this decomposition of water we get a long chain compound; we say, we hit it on the head and combustion starts. Can a picture of that sort of thing be given that will help us?

DR. HERMAN SCHLESINGER:—I understand that you are interested in some picture of how a long chain compound, for example, of a hydrocarbon like gasoline, is decomposed in the spark or during combustion. There are a number of theories at present with regard to the way such combustion takes place, two of which are probably the most suggestive. One is that the compound, being a long chain, has some weak point and that, with the increased agitation of the molecules and of the atoms within the molecules that occurs at a high temperature, the long chain arrangement becomes weak, breaks apart and leaves some atom or group of atoms which, let us say, has not got all the corners of the Lewis-Langmier cube fitted up and which, therefore, takes on or draws near to it some of the electrons of some other atom, for example, the oxygen atom. The other theory, for which there is not so much evidence, is that the oxygen atom or the oxygen molecule first adds on to the whole chain in some way that we do not yet understand, and that then a breaking occurs in some place. It is a very characteristic thing that a number of chemical reactions which we are accustomed to think of as taking place very readily are easily prevented. For example, you are familiar with the fact that if we put sodium, which is an extremely active element, into an atmosphere of chlorine, a very vigorous reaction results; that if we place sodium in contact with the air or with pure oxygen, it oxidizes extremely rapidly; or, for example, that ammonium chloride, when it is heated, decomposes into ammonia and hydrochloric acid. It is found, however, that if we put sodium into dry chlorine, the sodium and the chlorine will not react; and that if we take ammonium chloride, dry it, for example, over phosphorus pentoxide so that all of the moisture is gone, and then heat it, volatilization will occur without decomposition. If we take phosphorus and expose it to dry oxygen it will not burn; at least not unless you heat it to a fairly high temperature.

It strikes me that catalysis is a matter of extraordinary importance in the problem of the internal-combustion engine. I know very little about what has been done with regard to the internal-combustion engine, but the extremely important problem of the future is not merely the study of the simple chemistry of the combustion of the hydrocarbons in an engine cylinder, but the effects that catalytic actions, which are bound to be present in carbon deposits and the rough metallic surfaces, will have upon combustion.

PROF. DANIEL ROESCH:—I am seriously impressed by the importance of this subject and the mode of treating it in relation to the automotive industry. The coordination of information of this kind with that used by engineers will bring the ultimate result. I think that in 5 or 10 years from now the importance of it will be seen. Cooperation by the chemist, the physicist and the engineer is bound to clear up the situation.

MR. HORNING:—I would like to have Professor Lemon and Dr. Schlesinger consider a combination of oxygen and hydrogen and discuss the mechanism whereby a very high-frequency radiation may loosen the bond of hydrocarbons and thus facilitate their combining with oxygen. Our engineers are at the point where they would like to understand the fundamentals of this process.

COMBUSTION

DR. SCHLESINGER:—That is a question which just at present is one of those most discussed in physical chemistry. I will point out the way in which that question has come up in chemistry and the lines along which it is being developed at present. We all know that the higher the temperature is the more rapidly will a chemical reaction take place. Imagine a chemical reaction, say between the gaseous substances A and B. The molecules of A and the molecules of B are moving about at high speed, and occasionally a molecule of A and a molecule of B come together, with a chemical reaction as a result. We know that if we raise the temperature we shall increase the velocity of those molecules and, therefore, we can understand that the speed with which the chemical action takes place should increase with the rise in the temperature. When we actually measure the increase in the speed of the reaction with the rise in the temperature, we find that the increase in the speed of the reaction is many hundred times greater than he can account for simply upon the assumption that it is due to the increase in the speed of the molecules. How shall we account, then, for the fact that the velocity of the reaction increases so much more rapidly with a rise in the temperature than it should increase according to the purely increased speed of the molecules? We may assume that there are for each kind of substance, let us say, two kinds of molecule, or two states in which the molecule may exist, one in which the molecules are active and the other in which they are passive.

In the chemistry of 10 years ago, we should have said that perhaps some of the double bonds in a carbon compound had been ruptured, but we are beginning to inquire more deeply into the phenomenon of activation. There is a great probability that each molecule has a certain definite vibration-frequency and that if we put into the molecule energy of a wave-length that is capable of harmonically increasing the vibration-frequency of that molecule, we shall make it react more readily. Consequently we find two effects: (a) that certain substances are sensitive to light-rays in a certain way; for instance, we know that the photographic plate is much more sensitive to the shorter wave-lengths than to the others; and (b) when we put energy into a system by raising the temperature we increase the amplitude of those vibrations and, therefore, make the tendency to rupture the molecule greater.

The same problem is involved in the question which, as I have pointed out, is of such great importance in the combustion of fuel in the internal-combustion engine, namely, catalysis. Why should certain substances merely by their presence be capable of increasing the velocity of the reaction? They can do so in many ways, but one way is by being able to absorb radiation of a particular frequency and to give out radiation of a frequency that will increase the vibration amplitude of a particular molecule.

[illegible] at present are the ones that have not yet been fully or I may say even partially established, but some of the chemists are working very actively along these lines.

CHAIRMAN C. B. ZIMMERMAN:—The one thing that we should carry away from this meeting is that altogether too often in our engineering societies we follow questions from a purely mechanical standpoint. It has been shown tonight (we should) that chemistry and physics can enter into our problems and our understandings much more extensively than they have entered in the past. The real development in internal-combustion engines in the automotive industry, or in any other industry for that matter, is the application of the principles that are worked out in institutions such as the University of Chicago and by such coordination as we have had between Professor Lemon's excellent scientific conceptions and our engineering reactions from the mechanical standpoint.

IRRIGATION DEVELOPMENT

RECLAMATION projects must be developed with due consideration to the ability of the reclaimed land to compete on an economic basis with other cultivated land, and to the total output of American farm products in relation to the probable demand for them. The problem is one of peculiar interest to most of the States beyond the Mississippi, as the western two-fifths of the United States, embracing parts of the Dakotas and the tier of States immediately south of them and all the territory westward to the Pacific coast, is a region of deficient rainfall. For the most part it has an annual rainfall of less than 20 in. Corn-belt lands east of the Mississippi receive from 30 to 40 in. annually, while the fall over considerable areas farther east is as high as 60 in. In addition to the scantiness of precipitation in the large western area, the seasonal distribution is such that full benefit is not received in the growing season. West of the Rockies most of the rainfall occurs in winter. Within the area described variation in the quantity of precipitation occurs, but, while some favored regions west of the Rocky Mountains and on the Pacific coast receive more than 30 in. annually, in another larger area less than 10 in. is the rule, a condition comparable to that found in the Sahara Desert.

On the authority of the United States Reclamation Service, it is stated that "under the most complete system of irrigation possible it is probable that not over 5 per cent of the arid land can be irrigated in any one of the Western States." A half century of irrigation by private enterprise preceded Government entry into the irrigation field through the passage of the Reclamation Act in 1902, and nearly 9,000,000 acres of land was receiving an artificial water supply at that time. To a very limited extent the States had promoted construction of works, but difficulties in financing hindered the progress.

A summary of irrigated lands included in the Census of 1920 shows over 19,000,000 acres of land in 19 States actually irrigated. This includes enterprises of all kinds, both public and private. Improved farm-lands in the United States included 503,000,000 acres at the close of 1919. One-third more land than was actually supplied in 1919 can be watered without the construction of any new facilities.

The years 1920-21 and 1921-22 provided a severe test of the economic stability of the irrigation works. The irrigation farmer has a heavier financial burden than others, as the annual charges for operation and maintenance of the irrigation system continue whether the farm is paying or not. These are in addition to the installments payable on construction charges. For the years 1920 and 1921 the situation of many of the farmers on Government projects was so serious that relief acts were passed by Congress in 1921 and 1922 to enable them to continue operations. None of the accrued charges was remitted, but authorization was given to suspend the rule that water service be discontinued where payments were in arrears for more than a year. Normally some deficiency in payments occurs each year, but a considerable increase occurred in the 2 years mentioned. The average value of farm lands in Kansas was about $55 per acre in 1919, in Iowa nearly $200 per acre and in the Country as a whole, $57. Arid land has been made productive in the past at a cost of at least $60 per acre on the average for those projects that have received Government supervision.

Where the product of irrigated lands is sufficient to earn on the larger capitalization at the average rate on non-irrigated lands, the investment is profitable. Taking into consideration the probable higher cost of successive Government works, only lands of high productivity should be developed. Otherwise, the project farmer will find himself handicapped at the start in competition with the majority of producers.—*Commerce Monthly.*

THE ONE-CROP FARMER

AMERICA can never be made safe for the one-crop farmer. He will always be "in hot water" and in politics. His necessity will always be the political demagogue's opportunity to be elected to an office. Fundamentally, the woes of the one-crop farmer are the fuel and the flame of the Farmer-Labor party movement.

America never has been and never is likely to be unsafe for the farmer who practices diversified farming, the keystone of which is live stock. Firmly established and even today comparatively prosperous in many regions in many States, diversified or mixed farming, which always and everywhere is based on stock raising, is the Nation's greatest asset and chief safeguard in a time of economic and political upheaval.

The overwhelming majority of American land-owners are neither specialists nor wheat farmers. So long as mixed farming, with its foundation based upon improved live stock, continues to increase, as it has been rapidly increasing in recent years, American agriculture cannot be "ruined" by unprofitable prices for wheat.—*Breeders Gazette.*

Discussion of Papers at the 1923 Production Meeting

THE discussion of many of the papers presented at the recent Production Meeting of the Society, which is constituted without any exception of the remarks made at the meeting, is printed herewith. Another feature that is worthy of comment in this connection is the large number of question cards handed in.

For the convenience of the members, a brief abstract of each paper precedes its discussion. Members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort by consulting the index on the first page of the November issue of THE JOURNAL, as all of the papers for which discussion is given below were published in that number.

SPUR-GEAR GRINDING AND TESTING

BY A. J. OTT AND C. L. OTT

A GRINDING machine for finishing spur-gears is illustrated and described; claims are made that it will grind transmission gears on a production basis after they have been heat-treated, will produce correct tooth-contour, smooth finish and accurate tooth-spacing, these features being necessary in producing gears that are interchangeable and that run quietly.

This machine is of the generating type, its action being that of rolling a gear along an imaginary rack and using the grinding wheel as one tooth of the rack. The dished grinding-wheel is reversible, 30-in. in diameter, mounted below the gear, and can be swiveled to the right or left of the center position up to an angle of 25 deg. The work-spindle carries the indexing and the generating mechanisms at the rear, where they are accessible and yet are protected. Two or more machines can be operated simultaneously by one man, as a clocklike mechanism can be set to stop the work-carriage and the grinding wheel when the last tooth of a gear has been ground.

A drum-cam drives the work-carriage. Thin steel tapes are used to accomplish the generating principle; they wind and unwind on a pitch-diameter segment as the work-carriage is driven forward and backward, and produce uniform duplication of tooth-contour. Slight variations of tooth-contour can be made easily by giving a greater or a less angle to the wheel and also by varying the diameter of the pitch-circle or segment.

A machine for testing gears that have been ground is described also; it will develop the involute curve, indicate whether it is true or modified and test tooth-spacing. By means of adapters, engine-front spiral-gears, and bevel-gears, can be checked for accuracy of contour and for tooth-spacing.

THE DISCUSSION

CHAIRMAN JOHN YOUNGER:—An interesting thing brought out by Mr. Ott is that if we grind gears it will eliminate the tear-downs to a large extent, such as the overhaul work in transmissions. We are getting to the point in automobile construction where we are looking all the time for longer life of the parts. If we can take off a slight quantity of metal that causes interference, noise and wear, we will obtain a longer life for our transmissions, axles and timing-gears.

QUESTION:—How much is removed from the pitch-diameter in the grinding time required per tooth?

A. J. OTT:—Usually from 0.003 to 0.005 in.; sometimes only 0.002 in. The time required on the usual transmission tooth is 5 or 6 sec. per side of tooth. That is one grinding, or once around, which includes the in-and-out movement of the tooth to the wheel. Usually the operator goes around the gear twice.

QUESTION:—What is the limit of face-width on gears ground with your machine?

A. J. OTT:—For a six-pitch gear, it is 2 in.

QUESTION:—Why do you use a 30-in. diameter wheel?

A. J. OTT:—The 30-in. wheel is used so that we can grind up to a 2-in. diameter.

QUESTION:—What would be the daily production in 8 hr. on the gear first shown?

A. J. OTT:—That depends upon distortion and how many times it is necessary to go around the gear.

C. L. OTT:—It depends also on whether we want to grind the gear on both sides and how many machines the operator can use. On a 33-tooth gear, a man could easily run three machines, if he had that many available; if he had only two machines, the grinding time there should allow him to accomplish about seven or eight gears per hr., two grinds per side, which, in an 8-hr. day, would be 64; it would be about from 55 to 60 per machine. If we want to grind both sides, we can do that with two machines, or double the production if only one side is ground. A higher speed than this is maintained in one installation. This is 14 teeth per min. on a six-pitch gear, or 10 gears per hr. per machine.

QUESTION:—How are wide-face gears ground?

C. L. OTT:—Our machine will not grind over 2 in. on a six-pitch gear, and the average transmission gear is not that wide. This machine is made for that job. The average transmission gear is from $\frac{5}{8}$ to 1 in. wide.

QUESTION:—Is it necessary to true the wheel while the gear is being ground?

C. L. OTT:—If we had to true the wheel while the gear is being ground, the grinding machine would be no good. We use a 30-in. wheel, which provides almost 8 ft. of abrasive surface. There is no particular wear when the gear goes around once; it is impossible to detect it.

QUESTION:—Is it necessary to reverse the wheel to grind both sides of the tooth?

C. L. OTT:—It is not necessary to do that if the gear can be reversed. Reversing the wheel is necessary only in the case of stem gears and where it is desired to retain the same holding arbor. If we wish to reverse the

[illegible] gear and hold it with an outer support, we can do that but we do not advise that because it is very unhandy.

QUESTION:—Can spiral gears be ground on this machine?

C. L. OTT:—No, it is only for spur-gear grinding.

QUESTION:—How many teeth can be ground with one dressing of the wheel?

C. L. OTT:—I should say that on the six-pitch gear, with ordinary care, about 60 teeth should be ground with one dressing; after going around a 33-tooth gear twice, it would be advisable to dress the wheel. It depends also upon how good a wheel is being used.

QUESTION:—How are cluster gears ground?

C. L. OTT:—The cluster gear is usually made with the largest gear loose. The middle gear can be ground and then the largest gear can be ground in place after it has been riveted-on or ground before it is riveted-on. We can grind two gears in a cluster of ordinary design.

QUESTION:—What do you consider a commercial amount of backlash for a ground gear?

C. L. OTT:—The engineer at the motor-car plant usually tells us how much backlash is desired. I would say that, with closely held limits, on transmission cases, about 0.003 in. on each gear is sufficient.

QUESTION:—What are your grinding tolerances?

C. L. OTT:—We can hold a gear right up to size, provided it has sufficient stock. Taking a gear with oversized teeth, we can clean-up this gear after hardening and then test it for backlash. If, say, it is 0.002 in above the limit, we can put it in the machine and take off the 0.002 within 0.00025 in. at least. As for tooth spacing, we hold limits of 0.00025 in. tooth-to-tooth and use a 90-deg. check and 0.0015-in. accumulated error.

QUESTION:—How are bevel gears tested for involute curvature?

C. L. OTT:—We cannot do that on this machine. We can chart the tooth curve and test the tooth spacing.

QUESTION:—What is the approximate additional cost of grinding all the teeth of ordinary automobile transmission gears?

C. L. OTT:—I take it that the question means labor cost leaving out overhead. Taking a six-pitch gear for example and averaging eight gears per hour on both sides, all the way through, if the man were paid 80 cents per hr., it would be around 10 cents per gear. That would be rather high; say from 8 to 10 cents to do that on each gear. Usually six gears in the ordinary transmission are ground and the labor cost would be about 50 cents.

QUESTION:—How do you keep the cutting plane of the wheel exactly at the theoretical line of contact as the wheel or the diamond wears?

C. L. OTT:—Suppose we rolled a pinion along a rack. In like manner, as long as we roll the gear against the grinding wheel, roll it far enough out when it reverses and roll it back again, it will give the same curve. We have moved the wheel as much as $\frac{1}{4}$ in. lengthwise, and maintained that rolling, and no difference was noticed in the curve. So long as the roll is maintained, there is no particular point there.

QUESTION:—Is reduction of noise the chief advantage of grinding gears?

C. L. OTT:—Everybody wants noise eliminated in motor-cars. I think that durability is a good feature. One would rather get a gear for 60 cents than for $1. There are three benefits from grinding: accuracy, elimination of noise, and durability.

QUESTION:—Does grinding increase the load that can be carried by providing more uniform contact?

CHAIRMAN YOUNGER:—That is perhaps expressed by saying that the same load can be carried, but for a much longer time. That gives durability, the matter of long life, that is a large factor in automobiles just now. The life of cars is increasing steadily. Formerly, the average life was about 5 years. It is now in the neighborhood of 7 years and the curve of life is rising right along. Just such things bring this about.

QUESTION:—Does the wheel travel across the face of the tooth?

C. L. OTT:—The wheel does not travel at all; it revolves only.

QUESTION:—Will the gear-grinding machine accommodate gears of any involute form of standard or special pitch?

C. L. OTT:—I think it will; certainly it will, if they are within any reasonable limits. We can grind a modified involute form, and any pressure-angle up to 25 deg.

QUESTION:—Can the wheel be dressed during the grinding of a gear and still retain accuracy?

C. L. OTT:—I think that it would not be advisable.

QUESTION:—What method do you use to dress the grinding wheel?

C. L. OTT:—We have a double-worm hand-driven truing-device that is very substantial in design. It has a rocking motion. We have experimented with slides for truing, but the grit gets in. We have eliminated all of that trouble by making a lever-action device.

QUESTION:—Why do you follow the tooth form of a green gear instead of establishing a master form on the grinder?

C. L. OTT:—That point is raised by the manufacturer who has gears out in service, on account of his repairs. He would like to have the same curve sent out, so we are required to grind that curve. We think it is all right if the gears run quietly.

QUESTION:—A grinding finish was said to depend upon the amount of backlash desired. In what way?

C. L. OTT:—The only relation between backlash and grinding finish is that, if gears are cut with the desired backlash and we are expected to true them up afterward, more backlash results; that is all.

CHAIRMAN YOUNGER:—In other words, you must have a full-stock gear.

C. L. OTT:—We should have a small allowance, say 0.002 or 0.003 in. on the side.

QUESTION:—If noise is not a factor, what can be said as to the wear of teeth that are ground and those that are unground?

C. L. OTT:—We have statements from two large engine companies in Detroit. They say that, from actual tests, the ground gear lasts far longer than the unground gear.

QUESTION:—Does a true involute curve produce a quiet gear?

C. L. OTT:—We have found by experience that, if no eccentricity in the spacing of the teeth occurs, the curve can vary somewhat and we still get about the same results so far as the perfect involute is concerned. I feel that the curve ought to stay a little bit away from that.

QUESTION:—Have you made any advance in regard to bevel grinding?

C. L. OTT:—We have not taken up that proposition yet.

QUESTION:—What is there to stop water from getting between the grinding wheel and the bearing of the spindle?

C. L. OTT:—Because the wheel is below the work,

water or anything of that character will have a tendency to get into the bearings, but we have that well safeguarded. We have two splash-rings there and rely on centrifugal force to help us out; also, we use a double packing-ring. We have no trouble there.

QUESTION:—Were the tooth curves shown taken from production or from an experimental test?

C. L. OTT:—From production.

QUESTION:—Is the cutting face of the plane a plane surface only?

C. L. OTT:—Yes.

QUESTION:—Is that modified at all?

C. L. OTT:—There is absolutely no modification.

CHAIRMAN YOUNGER:—Do automobile manufacturers pay any attention to securing quiet gears in England?

W. HADLEY[1]:—Certainly. Owing to the high speed at which the English engines run compared with those of the American cars, we have to get down to this very thoroughly.

CHAIRMAN YOUNGER:—They do much gear-changing in Europe. Do they insist upon quiet second and third-speed gears?

MR. HADLEY:—Yes.

CHAIRMAN YOUNGER:—Is that obtained by grinding, by care in manufacturing or in other ways?

MR. HADLEY:—That is taken care of by grinding.

DEVELOPMENTS IN PRODUCTION GRINDING IN THE AUTOMOTIVE INDUSTRY

BY OSCAR A. KNIGHT

IN production grinding the progress made during the past few years has been along the line of grinding multiple parts simultaneously, such as piston-rings, ball and roller-bearing cups and so forth. This kind of grinding brought about the use of wider wheels to cover the entire surface of the work, whereas formerly narrow wheels had been used with the traversing table method. With the development of these operations came the cylindrical grinding of square and distributor cams; also square shafts, using the oscillating cam-grinding attachments; piston-relief grinding with the same attachments; and two-wheel or double-wheel grinding for such parts as steering-knuckles and pinion shafts of different diameters or where two diameters are separated by some protrusion, as in steering-gear worm-shafts.

To accomplish these new operations more care has been taken to build machines that are heavier, stronger and more accurate so that operators can place greater dependence upon the mechanisms than was possible with previous machines. Greater care has been taken to balance the grinding wheels more accurately to overcome imperfections in finish and to eliminate excessive repairs on the grinding machine itself. Some of the new attachments, mechanisms and grinding machines are described in detail in the paper.

In conclusion the author states that the automotive industry has become the chief element in machine-tool business in the Country at the present moment and therefore the principal factor in forcing new developments in machine-tool design. He also points out the importance of a quality product to serve the needs of the automotive industry adequately.

THE DISCUSSION

CHAIRMAN JOHN YOUNGER:—Originally, crankshafts were very small in diameter. We made them as near the minimum size as we possibly could. Then we increased their diameter. We were satisfied with this for a while, but this year there has been another general movement toward again increasing their size. In our big-diameter crankshafts, to what extent are we eliminating the use of the steady-rest while grinding? Is it possible to do away with it?

O. A. KNIGHT:—Several factories run their machines without steady-rests; but their production is very small compared with that of those who support the pins with a steady-rest.

CHAIRMAN YOUNGER:—Does that mean that the thrust of the grinding wheel is greater than the explosion thrust?

MR. KNIGHT:—A wide-face wheel will force the work away from the cutting surface of the wheel unless we back the work up. The length of the work being done should be as short as possible between centers; the purpose of the steady-rest is to hold the work on the center line. It eliminates the vibration of these heavier shafts, which vibrate more than the lighter shafts did.

CHAIRMAN YOUNGER:—Then, in future design, we will have to consider tooling reactions as well as the reactions in the machine.

MR. KNIGHT:—Yes. I believe we shall always have to support a crankshaft with a steady-rest to make it as round, straight and smooth as is demanded by the trade.

QUESTION:—What means have been developed to balance grinding wheels?

MR. KNIGHT:—Several means are provided for balancing wheels. The right way to balance a wheel is to balance the wheel itself. If it were possible for wheelmakers to puddle a wheel in such a way as to cause a uniform balance throughout its life, that would be ideal. That has been accomplished on an experimental basis but it has not been carried out in production. Eventually, no balancing devices on the machine itself will be required, because the wheel that has been made true to its respective size will be in balance throughout its life. Lead has been placed in one side of a wheel to offset a heavy side opposite, but the wheel sleeves that hold the wheel have been equipped also with balancing flanges. The wheel is in balance when received by the user, but as it wears smaller during its use, it sometimes goes out-of-balance and must be rebalanced.

QUESTION:—What limits for pin-axis and shaft-axis alignment do you consider possible?

MR. KNIGHT:—Anything less than 0.002 in. will retard production, but I believe that 0.002 in. is a good figure to consider as a good productive product from good crankshaft machines.

QUESTION:—Do you consider lapping after grinding necessary on crankpins?

CHAIRMAN YOUNGER:—I have heard recently of a machine for buffing crankpins that is very similar to a grinder.

[1] English representative, Lees-Bradner Co., Cleveland.

MR. KNIGHT:—Many different qualities of crankshaft are made. The automotive engineer decides whether he wants the quality of crankshaft that costs more. The buffing operation is, however, a good one. It takes off the feathers of heat and prevents that from going into the bearing of the connecting-rod or the bearing of the crankcase itself. Every revolving shaft in a certain engine is buffed in the direction it rotates in the engine. The designer of the engine says that eliminates much bearing wear and bearing trouble that would occur if the shafts were polished or buffed in the opposite direction.

CHAIRMAN YOUNGER: It is understood, of course, that such lapping or buffing must be done with the same accuracy as the grinding is done.

MR. KNIGHT: I have known of work being called buffing that was not buffing; it injured the pin as it came from the grinding machine, rather than having improved it. If correctly performed, buffing is an improvement after the average medium-rate crankshaft has been finish-ground. I believe that the crankshafts for the best grade of car should be lapped by the old-fashioned lapping method. Buffing will never make a perfectly round object. It will follow the shape that has been made in the grinding machine, and all products from grinding machines are not perfectly round or perfectly straight; but they are within limits of accuracy that are satisfactory to the maker of the product.

CHAIRMAN YOUNGER:—What is the wheel cost for a 2-in. shaft, for example?

MR. KNIGHT: I cannot state exactly. The rough-grinding on pins costs 4 cents per pin; roughed from the black stock. That includes diamond and wheel costs.

CHAIRMAN YOUNGER: Is the wheel cost almost negligible in the cost per shaft?

MR. KNIGHT:—Yes.

QUESTION:—How much does the oscillating wheel travel?

MR. KNIGHT:—Nothing would prevent them from traveling ½ in. if that were found necessary, but any movement from 1/32 to ⅛ in. is sufficient to break-up the grain lines, for which purpose the attachment was developed.

QUESTION:—Is the trend toward centerless grinding-machines where larger limits are allowed?

MR. KNIGHT:—The trend is great toward the centerless machine.

CHAIRMAN YOUNGER: Does it mean differences in tolerances and limits?

MR. KNIGHT:—Just as close accuracy can be secured from the centerless machine, if great care is taken in preparing for the closer limits. The greatest production from centerless-machine grinding will be secured with wide limits for accuracy and finish. The centerless machine is doing wonderful work today in the grinding of pieces that have no centers or pieces where centers can be removed. I know very little about centerless grinding except what I have observed, but I think the direction of a large volume of work is toward semi-automatic, automatic and centerless grinding, but centerless grinding has a limit as well as crankshaft grinding or any other kind. Production on piston grinding has a limit because the wall of the piston is either thick or thin. If it is of cast-iron or steel, and those limits have to do with centerless grinding as they have to do with all other kinds of grinding, it is the limit of the grain of the grinding wheel, the wall of the piece being ground and the accuracy demanded by the maker of the pieces to be ground.

QUESTION: Do you see any fundamental obstacle to the general use of ball bearings for carrying the main spindles of grinding machines?

MR. KNIGHT: Yes.

CHAIRMAN YOUNGER:—Is there any objection also to the general use of roller bearings for such purposes?

MR. KNIGHT: I have seen experiments carried through for the use of ball and roller bearings for the wheel spindle, and I would never expect them to be used for precision grinding. The bearing surface is not sufficient to withstand the present out-of-balance wheels. Chatter-marks constitute the greatest trouble we have in grinding. Almost always, on precision work, when ball or roller bearings have been put into the wheel spindle as a bearing, chatter and mottle troubles have been increased. The smooth bronze or babbitt-lined bearing with a force-feed oiling system is the best bearing for wheel-spindle construction. For internal work, a number of very successful ball-bearings are used because of the high speed, but the speed of the small wheel for internal grinding does not affect the little inaccuracies of the balls of the ball bearings. The cutting particles in that small wheel run so fast that they pass over or split into many times the number of chatters that would occur if they were made in a cylindrical machine or precision-cylindrical machine wheel-spindle bearing.

CHAIRMAN YOUNGER:—You said that you took the gears out of the machine and substituted a silent chain. Were those gears of cast-iron?

MR. KNIGHT:—One member was hardened steel and the other cast-iron. The trouble with the gears is not that they are *gears* but is attributable to the difficulty of making *good gears*. Only by the use of gears could we secure power and production until we used the chain. Engineers who formerly were afraid to use chains seem not to be afraid to use them now. We find that they are very successful in many different types of machine-tool, especially where the machine-tool is used for precision work. The chain or soft belt has eliminated our troubles when we have found a poor quality of gears in any particular machine.

QUESTION:—Can the reciprocating-wheel device be installed on standard-make grinding-machines now in production?

MR. KNIGHT:—The device mentioned in the paper can be applied to any machine made by that concern.

QUESTION:—What developments have been made in grinding ring-grooves in pistons?

MR. KNIGHT:—I know of no production developments.

QUESTION: Why is wide-wheel grinding limited to $9\frac{3}{4}$ in.?

MR. KNIGHT:—That is as far as we have had experience. The wheel-makers say that no limit exists as regards the making of the wheel but, the farther away we get, the longer or larger are the spindles that are needed to withstand the pressure on the end of the spindle. To put a bearing on the outside of a wheel or on the inside of a wide-face wheel is not good practice, because, when the wheel is changed, that bearing must be removed and then the alignment eventually will be lost between the bearings supporting the wheel.

CHAIRMAN YOUNGER:—What is the maximum width of face used?

MR. KNIGHT:—It is 10 in.

QUESTION:—No mention has been made of the hydraulic traverse. What is your opinion regarding this?

MR. KNIGHT:—It is not very old as yet. It is working out very nicely on internal machines but in the case of cylindrical grinding, where so much water and so

much lubricant are present and so much necessity exists for protection against the grinding material that is removed from the pieces and the splash of the lubricant for keeping the work at even temperature, not very many grinding-machine builders have gone into that method of drive for precision-work.

QUESTION:—Have you used the wheel-reciprocating device in grinding cams?

MR. KNIGHT:—No, except in an experimental way.

QUESTION:—To what extent has the diamond been replaced by other truing devices?

MR. KNIGHT:—In automobile plants, about two-thirds of the grinding machines are now using mechanical devices for truing wheels, and they are very satisfactory for both roughing and finishing.

ARTHUR C. PLETZ[2]:—I do not wish to contradict Mr. Knight's statement by saying that the lead-lapping process is not the best thing to use, but I believe that we have not developed a process in lead-lapping that would be practical on crankshafts. We build crankshaft-polishing machines and we use the felt wheel for polishing. I agree that, if there is a slight out-of-round effect, it will be maintained; but I think it is the best commercial proposition obtainable. The departments in which I have been recently that polish crankshafts have always used the hand method. We believe it is not the best method; it is difficult to get men to handle the "lemon-squeezer" type of polisher. It is wearing on the men's arms and does not produce the best finish. I believe that we get the production on our machines; in fact, we can better the production in most cases. In a plant where they turn out from 600 to 700 crankshafts per day, I was asked: "What is your production on the crankshafts?" I answered: "Sixty, probably 70, crankshafts per hr. with three machines." I was told that they had three high-speed lathes, or three speed-lathes, and that they maintained this production. I was shown some of their crankshafts and believe they were not improving them very much by their method. Our machine would maintain that same production and give them a decidedly better finish. In some cases in which a very high-grade finish is wanted, probably our production would not be as high as that of the lemon-squeezer type of polisher, or the hand-method, but I know it would be decidedly better and give a longer life to the crankshaft bearings.

Our machine is very much like the grinding machine. We use very hard felt and dress it with a certain preparation. For instance, on a four-cylinder crankshaft we will have one machine set-up with three wheels to handle the three main bearings; the other machines will have two wheels and will handle the pin bearings. The operator puts the work in between centers on his main bearings or into his pot-chucks for his pin bearings. The wheel is the full width of the bearing; he brings it right up to the work, holds it there for a few seconds, brings it back and takes out the crankshaft.

MR. KNIGHT:—What is the purpose of that buffing operation?

MR. PLETZ:—Microscopic photographs taken of the crankshafts show that we get a much higher finish and a much smoother surface; this means a longer life for the bearing.

MR. KNIGHT:—This is because the grinding operation was a poor one. You ought to improve the grinding operation.

MR. PLETZ:—We are improving the grinding finish.

MR. KNIGHT:—You follow the shape of the piece, whether it is round or straight or tapered and, while you do improve the quality of the finish, you take away the ground finish that was put on it with the grinding machine, do you not?

MR. PLETZ:—Yes.

MR. KNIGHT:—That proves that the operation of grinding has been a poor one.

MR. PLETZ:—I find that internal-combustion engine-builders polish the bearings after they are ground in practically every plant. They change the ground surface because this is necessary. I believe there is not a crankshaft that goes into an engine that is not polished after it is ground.

MR. KNIGHT:—That is true.

W. D. BLISS:—A grinding-machine company always asks what degree of finish is wanted. Mr. Knight spoke of the degree of finish desired and its relation to production. I have never been able to get any set of standards that would determine the finish desired. If any such thing as a standard degree of finish exists, how do you tell another man what degree of finish you want?

MR. KNIGHT:—One company has been striving for many years to classify the standards of finish into rough, commercial, reflective and highly reflective. One can read a newspaper held up against the reflective finish; it is one that will reflect what is held against it. When we are requested to make a finish, we know that we have to make it to suit that customer; sometimes we think it is poor and he thinks it is good, but we suit him. We get more production with a commercial finish than we do with a reflective or a highly reflective finish. More time is required to turn out a quality job. The average work that we do is the commercial finish, of course. All the factories are getting into the quality work. Everyone wants the finest grade of finish and the greatest accuracy. Machine-tool companies are building apparatus to produce that fine quality as rapidly as the commercial finish and commercial-limit work.

C. F. WASSERFALLEN:—We made a separate operation on finish. We never touched the bearing, regardless of the speed at which it was running, even at 3600 r.p.m., and we made two operations. In fact, it was the first commercial grinding done in this Country. We roughed it and then we finished it; we made good speed and we never touched the bearings. We had three finishes: rough, commercial and mirror. We asked for mirror finish and we got it; it was better than any lapping job. Defects could not be detected by measurement. I believe lapping or buffing is not necessary. I believe it is not as cheap as putting the work through a second operation with a small amount of grinding; and the latter is positive.

W. G. CAREINS:—Mr. Knight said that his company had made experiments with the oscillating attachment on cam grinding. What were the results?

MR. KNIGHT:—They are very interesting. I believe we will recommend it for this class of work. Grain-lines are produced in cam grinding just as they have been in every other kind of grinding; the hand movement of the table-drive apron handwheel has always been necessary in cam grinding to break up the grain-lines. Cam and camshaft grinding have been the most difficult work we have had to handle. Accuracy is and always has been wanted on cams, and more so now than ever before. If we can break-up the grain-lines and make the finish of the same quality as though made by a traversing operation, instead of a straight-in operation, that is the purpose of the oscillating device, the reciprocating-spindle attachment. It will be attached for cam grinding

[2] Secretary and general manager, Morris Machine Tool Co., Cincinnati.

as well as for every other kind. It also will be used for shoulder grinding on semi-automatic and automatic machines. Where it is desirable to dwell a little longer in the shoulder, the cam in the device will be made in such a way as to cause this dwell period the same as though the wheel were traversing, and the reversing mechanism will let the wheel dwell there a moment to grind out the V.

MR. CARLSON:—Some of the speakers are confusing lapping and polishing. I have always considered them to be entirely different operations.

JOHN A. C. WARNER:—With reference to the finishing of piston-ring grooves, the Society has made an investigation of the processes that are being used by the various manufacturers. It has been found that very few are using a grinding operation. Most of them are doing the finishing by using burnishing tools, such as a burnishing file. The results of the investigations are to be published in an early issue of THE JOURNAL.

H. F. HARRISON:—Is there any general trend toward rough-grinding crankshafts as compared with rough-turning?

MR. KNIGHT:—The rough-grinding of a crankshaft pin was begun about 1909, when the forged crankshafts were brought-out with all pins forged in shape. Then, the most successful method of grinding crankshafts was to grind from the black stock or forging, in what we called a rough-grinding operation, and to pass to a second machine for the finish-grinding operation. The cost of grinding wheels increased, the keeping-up of dies was found to be expensive and, to make it expedient to grind crankshafts from the black stock or the forging, $\frac{1}{4}$-in. of stock must be maintained. By the turning method, when larger production turning-lathes were developed, manufacturers could neglect the stock-allowance in the up-keep of their dies and, because of the expensive wheels, it became practically impossible to compete by rough-grinding from the black stock. The trend will not be toward rough-grinding of crankpins from the black stock until better results shall have been obtained from our experiments or more knowledge secured in regard to the automatic-wheel in-feed grinding of crankshafts referred to in the paper. When that time comes, perhaps we can talk more about the re-establishment of the rough-grinding from the black stock. The way to grind crankshafts is to rough-turn them first, leaving from 0.030 to 0.045 in. of stock, and then to make a rough-grinding operation and a finish-grinding operation, which decreases the excessive cost due to expensive wheels.

THE HUMAN ELEMENT IN PRODUCTION

BY W. F. JAMESON

PRODUCTION is largely dependent on the human element, which is called by different terms according to the degree of intelligence expected from persons of different ranks; varying from ordinary stupidity among those of low intelligence to the "errors of judgment" of those higher up, it has been defined as a "temporary lack of application of one's attention to the thing at hand," and its effect on workmen of various temperaments is to lower production. Concentration is shown to be the central truth and the cause of one man's superiority to another. When supplied with an incentive, such as that of feeling that he is working for himself, a workman will concentrate his attention on his work with profit both to himself and to his employer. But apparently insignificant things preying on his mind will often cause a lack of concentration. Education is an endless process of growth and accomplishment. The motive back of the desire for a college education is the gathering of a fund of knowledge and experience that will enable one to cope better with the problems of life. A going manufacturing company offers real problems for solution and obstacles to be overcome. Every job can be made a training school of character if the holder will make it so; the production game furnishes everything necessary for growth. Inertia is the great obstacle, while auto-suggestion, on the other hand, is of great assistance in instilling spirit into one's work. The determination continually to learn something new, to overcome all obstacles and to take advantage of opportunities that are presented will not only make the time pass quickly but will also increase efficiency.

THE DISCUSSION

PRESIDENT H. W. ALDEN:—A paper such as this is a good healthful thing for us to consider seriously. Most engineers, when they waste money, get their bumps from the management. Most factory organizations get their bumps when they fail to provide proper equipment for producing the work. So far we have focussed our attention in industry principally on designing things that can be produced economically and on the tools that can produce them economically. We have spent precious little time on the human end of it, and this is probably the biggest end. We are very apt to overlook the big bet in this life, right along. Undoubtedly, we have been overlooking it in the automobile field, the same as in other fields.

Recently, I was talking to the general manager of a fairly large steel company that has a well-managed plant about what effect the 8-hr. day would have on the cost of steel. He said that before answering the question he would wait and see the result of certain experiments that they had in progress. The experiments were in the nature of just the subject matter of this paper, the devoting of his time to the men and the conditions under which they worked, and giving the men a chance to show what men can really do. He said he had about reached the point where he could predict that, because of the changes in running his plant which he was putting into effect, the cost of steel per ton would go down when the 8-hr. day was in full swing, and would not go up. He might just as well have done that before, but the incentive did not present itself until he was faced with the 8-hr. day in place of the 12-hr. day. He is a pretty hard-headed man, and I thought it a good illustration of what can be done when we use our brains. I am inclined to think that most of us who manage men do not make use of as much brain-power as we could. The point on which Mr. Jameson touched particularly is one that I know from my experience. When the work comes out of a department wrong, when any labor trouble springs up or when things do not go just exactly right, the trouble is most apt to be with the foreman. As they say in the Army, if we have good top-sergeants in the regiment, we do not care what kind of a colonel we have.

QUESTION:—What method does Mr. Jameson use to reward the men who have shown evidence of concentration and of thinking out their own problems?

W. F. JAMESON:—The man pays himself his own reward. This comes in the satisfaction that he gets in

being loyal to himself; to that extent he pays himself his own dividend. He is working for his own interest.

PRESIDENT ALDEN:—Can you sell that idea to him?

MR. JAMESON:—Absolutely. This has been done time and time again. It is not a cure-all to be handed out on a silver platter for any and all classes of workmen. Some classes we cannot touch with it. To grasp it requires some intelligence. Some men have only the machine side to offer and nothing more; but, so far as we carry the proposition, we can sell them on the idea that the benefits accruing from it are well worth the effort put forth.

QUESTION:—Will you give one or more specific instances of securing the interest of the man?

MR. JAMESON:—Those who have tried the selling game know that the first step is to get the attention and then arouse interest and the like. I intimate in the paper that it requires pretty good salesmanship sometimes to put this over; but, in my experience, I have found it very easy to get the attention of almost any individual in a proposition similar to this, regardless of his station in life. I have tried it on various classes of men purposely to see how it takes root, to determine the kind of ground and how fertile the ground should be for the idea to take root and grow. You would be surprised to see how the men listen. All depends on the caliber of the individual as to the fruit borne.

QUESTION:—What are your recommendations for starting an idea of this nature in the average manufacturing plant?

MR. JAMESON:—I have stated that this idea cannot be applied to a group collectively, or in a wholesale manner. It is new and a little out of the ordinary; possibly it is just a little advanced for these times. But, in our respective connections with the organizations with which we are associated, most of us know that endless conflict which is going on in production today. There is an unrest; there are always the two extremes. As long as a workman shows a spirit of fight, you will never get anywhere; it is blow for blow. But, if you turn every man's attention inward on himself along the lines stated, he will work out his own salvation. A man might pick half a dozen men in his department who will listen and reason and understand the principle that is set forth in the paper, principally on account of their selfishness. That point is important; we cannot get away from the fact that every one of us is selfish; it is the selfish gain that every one of us is capitalizing in this business. The thought: What do I get out of this? prompts most human action. Teach this to say one individual in each department. The subtle influence that this man has on his fellow man, if he exhibits it in his work, cannot help but multiply. No line can be drawn as to how far one can reach with that much effort expended. Some people may consider these principles "Sunday-school ideas," as one man expressed it. If they are Sunday-school ideas, it is time to inject a few of them into production. But the conditions are not right for coming out with a definite positive program and sweeping it in. That cannot be done; there is too much indefiniteness in the human being, and in his response to any action you take toward him. Therefore, the only way to bring such things about is by the gradual process of leavening one measure of meal and letting it leaven the whole loaf.

PRESIDENT ALDEN:—A subject such as that which Mr. Jameson has presented is so intangible and so non-responsive to the slide-rule that it is a very difficult idea to get across successfully. Without doubt, if we knew how to do all these things we could speed-up production, lower costs, get the standard of living where it belongs and have things as they ought to be. I think this is about the only way it will be done. If we could get the laborer to use his brains, we might get out of the difficulties we are in; but you never can get that unless the man over him uses his brains. That is true all along the line.

THE APPLICATION OF CONVEYOR EQUIPMENT TO A SMALL PRODUCTION PLANT

BY H. P. HARRISON

TO install conveyors in a going automobile manufacturing plant of moderate size, without interrupting production, and with a minimum amount of rearrangement of the plant and an investment commensurate with the saving to be effected, was the problem, the solution of which is herein described. The conditions that determined whether power-driven or gravity-actuated conveyors should be used are discussed and the various types required for handling raw stock, for machining operations, for sub-assemblies and for finished assemblies are indicated. Among the operations for which conveyors were found particularly advantageous are those of handling cylinder castings from the storage of raw stock to the stockroom for finished parts; carrying cylinders between various machining operations and from the inspection bench to the storeroom for finished cylinders; machining transmission cases; carrying rear-axle gearcases through machining operations and delivering them to the starting end of the axle-assembling line; handling parts between departments and machines; assembling transmissions, engines, and front and rear axles; carrying axles to the washing and paint-spraying machines, thence to the chassis assembling line; handling the trimming of open bodies; the final conveying of chassis and finished cars; and handling the finished cars through the final-inspection and touch-up operations. The conclusion reached is that the use of conveyors not only pays, but pays well.

THE DISCUSSION

QUESTION:—How are the cylinder carriers returned?

H. P. HARRISON:—On the downward traveling side of the elevator chain. They are fed in at a point just below the delivery section, delivered at the basement level automatically and dropped into a pile at that point.

QUESTION:—Could the engine have been brought to the chassis at ceiling level, thus saving floor space?

MR. HARRISON:—Probably it could have been. The conveyor used for this purpose is a parallel installation of the final-car conveyor adapted to handling engines, which was installed originally for additional production of assembled cars. It is simply a duplicate of the belt conveyor on which the car is built and, not being required for that purpose, was equipped to handle engines.

QUESTION:—What will the 40-per cent saving in the cost of handling, which results from the conveyor system, mean in percentage of saving in the cost of the car?

MR. HARRISON:—The 40-per cent saving refers to the

[illegible] and would probably amount to a great deal saving in the labor cost of the car.

QUESTION:—Are all conveyors moving continuously after the operations are performed?

MR. HARRISON:—Yes, they are driven by variable-speed motors that can be set for any desired amount of production and move at a predetermined rate throughout the day.

QUESTION:—Do you contemplate applying conveyors to carrying small finished pieces from machines?

MR. HARRISON:—We have not devoted much thought to that. One installation of this type that was tried was a failure because of our inability to keep men at the ends of the conveyor to load the work and take it off as the conveyor attachments passed. The time spent by a man remaining at those points continuously would be far greater than that required to truck the parts in [illegible] to the finished-stock room.

QUESTION:—Why were there so many conveyor failures in the older installations?

MR. HARRISON:—It seemed possible to move cylinder castings to an operator and take them away at a certain speed. The fact that we would not do that developed immediately; the control of machine breakdowns and matters of that nature defeated the idea of taking the work away from the man as fast as we desired. We find that the gravity installation does all that we wish the conveyor to do and, at the same time, it provides some allowance for such things as breakdowns and other production delays.

QUESTION:—How are the cylinders cleaned?

MR. HARRISON:—They are sand-blasted, inside and out, at the foundry. When received the cylinders are cleaned at the end of the machining line in a kettle provided with a steam coil for heating and with steam jets for atomizing and spraying steam and hot water into the valve-ports and the cylinders. This operation supplies enough heat to the cylinder casting to dry it, after which it receives a coat of paint.

QUESTION:—Is there an auxiliary method of moving parts in the event of a conveyor unit breaking-down?

MR. HARRISON:—None, except resorting to the old method of using hand-trucks. This, of course, requires emergency men and methods, but we have had no breakdowns of conveyors that delayed us more than 1 or 2 hr. We operate only 8.7 hr. per day and, ordinarily, are able to remedy any breakdowns in the interval between one day and the next. Very little hand-moving has been required in the year that we have had the installations in operation.

QUESTION:—Do you weld or plug blow-holes in the cylinder walls?

MR. HARRISON:—When the hole does not go entirely through the cylinder wall we use the common method of welding with nickel wire and peening the resulting weld into a smooth surface before finish-grinding. We have used this method with good results for about 5 years. When the water-pressure test shows that such a defect passes entirely through a casting, the casting is discarded immediately.

WAGE-INCENTIVE SYSTEMS

BY EUGENE BOUTON

NUMEROUS wage-incentive plans are now in operation in the various automotive and other industrial plants; but the proper system to install in a given plant, whereby unit costs will be maintained level and at the same time proper cooperation from employes will be obtained, has always been open to discussion.

One plan now in use by the company represented by the author is straight individual piece-work on small-parts operation where one, two or even three operations complete the particular part, and where only one or two operators are engaged in machining or assembling the particular unit; whereas, on the major machining and assembly units such as cylinder-block machining and engine or complete-car-assembly units group piece-work is employed throughout the entire plant.

By the installation of individual and of group piece-work, unit costs are maintained level at all times; in addition, the workmen employed are able to determine very easily by their own calculations what they have earned either daily or at any hour of the day. This is in direct contrast to other and more complicated systems wherein unit costs are not maintained over given periods and workmen in many cases are required to work for a complete pay-period without being able to ascertain their earnings over and above their guaranteed day-rates.

Still another feature of the group and the individual piece-work plan is the small clerical force necessary for the functioning of the system. The company and its employes feel that the wage-incentive plans now in operation have met all of the principal objections generally experienced with other wage-incentive systems.

THE DISCUSSION

EUGENE BOUTON:—Supplementing my paper, Fig. 1 shows the day-work authorization-card. Whenever there is a breakdown in equipment, lack of materials or the like, and it is necessary to make an allowance to the group for delays, this form must be filled out by the department foreman and approved by the production manager and the time-study department before the amount due can be paid. We have found that this method controls the amount of day-work allowances, so that no day-work will be paid for unless the group is entitled to it.

PRESIDENT H. W. ALDEN:—What effect has a group plan had on labor turnover?

MR. BOUTON:—It has reduced the labor turnover in our plant.

PRESIDENT ALDEN:—Has the labor turnover been eliminated?

MR. BOUTON:—Not entirely. A certain percentage of labor turnover is a good thing for any plant. In individual piece-work, or in individual effort applied to jobs where a group would do much better, we find a closer cooperation among the employes. The men try to help one another. The attendance is much better.

QUESTION:—Under your plan, an increase in a man's rate is paid out of subtractions from his fellow-workmen's compensation. How do they accept that?

MR. BOUTON:—If certain members in a group apply themselves and are on operations that require exceptional skill, they should receive a greater reward than the new men entering the group, or unskilled men. They merely receive a higher pro-rated share of the earnings of the group. It is up to each man to improve himself as much as possible. However, a limit exists as to how far a man can go. The management has specified the high limit; when a man reaches it, he can go no farther so far as getting a higher rate is concerned.

Often, when one man is shiftless and does not want to work, the men run him out. However, no matter what his personality may be, if he is a good worker in the group, seldom, if ever, is a man run out of the group.

QUESTION:—How are the men in each group informed of their earnings each day?

MR. BOUTON:—The foreman gets a copy of the group piece-work report and, if the men care to know what their earnings are for the preceding day, he can tell them. After the group has been in operation for some time and it produces say 50 to 60 units per day, the men can gage what their earnings are very readily.

QUESTION:—If an inexperienced employe is behind in his work, how long do you carry him at the day rate?

MR. BOUTON:—Generally, 2 days are allowed for a new employe to become accustomed to the operation to which he is assigned. It is to the interest of the remainder of the group to assist that employe to learn his operation as quickly as possible. If he cannot come up to the speed that is required, he must be taken out of the group.

QUESTION:—In a group of five men, how are you sure that the best man gets the most pay.

MR. BOUTON:—A time-study man assists the foreman in determining which men are the most skilled or what the heavy operations are. In rating the men considerable good judgment must be used.

QUESTION:—If an operator is transferred to a lower piece-price job, how do you adjust his pay, provided he is efficient on the transferred job?

MR. BOUTON:—The lower piece-price work on another job would require less men in the group. The man's earnings would not be affected.

QUESTION:—What do you consider a fair percentage to add for fatigue and contingency to the actual time-study schedule?

MR. BOUTON:—That depends upon the nature of the job. Some jobs are fast and require great accuracy. Some companies allow 10 and some 20 per cent. The machine-tool builders generally make estimates on a 20-per cent basis. The percentage depends on the job.

QUESTION:—What is done if a piece-price is set too high?

MR. BOUTON:—We do not cut prices because the earnings of the men are too high. The only way a price can be cut is through a change in the set-up where tooling is involved, or a change from one machine to a different type of machine. If the workman makes considerably more than was generally allowed, we must put up with it.

QUESTION:—What do you consider fair pay per day on a piece-work basis?

MR. BOUTON:—The standard of wages is fixed by the management and the base rates from which the prices are set are determined in that way. Each city has its standard of wages and each workman should earn the standard wage paid in whatever locality he is employed.

QUESTION:—What is the average scrap-allowance?

MR. BOUTON:—On some jobs it is possible to continue for some length of time without getting any scrap; other jobs are so precise or complex that perhaps 2 per cent would be a fair allowance for scrap.

QUESTION:—Do you charge the group for only the labor on a spoiled article or for the material also?

MR. BOUTON:—When a deduction is made from the group for the scrap, only the labor and time expended on the job are deducted.

QUESTION:—Does this system guarantee a minimum pay?

MR. BOUTON:—It guarantees the minimum hourly day-rate. However, if the operator can make only his minimum hourly-rate, we cannot afford to tie-up a machine with him and keep him indefinitely. He must make the base rate or the number of pieces specified on the route sheet to be satisfactory on the job. One reason the hourly production is shown on the route sheet is that the operator is expected to produce that many pieces.

QUESTION:—How long have you had this system in operation?

MR. BOUTON:—Approximately 6 months.

QUESTION:—When working on straight piece-work, should the rate be cut when a man's earnings, due to increased output, achieve the hourly rate of other men of the same grade?

MR. BOUTON:—No, it should not; if the operator becomes skilled and fast enough to make that amount of money, he is entitled to it.

DAY WORK AUTHORIZATION

Dept ..... Date .....

Name of Part ..... Part No. ..... Group No. .....

Description of Work

.....

Reason for Day Work

.....

PAY Piece Work / Day Rate at per

Requested by .....

Time Study Dept

Approved .....

FIG. 1. THE DAY-WORK AUTHORIZATION-CARD THAT MUST BE FILLED OUT BY THE DEPARTMENT FOREMEN WHENEVER BREAKDOWNS IN EQUIPMENT, LACK OF MATERIAL OR A SIMILAR OCCURRENCE NECESSITATES MAKING AN ALLOWANCE TO A GROUP FOR DELAYS

QUESTION:—Has the plan increased the inspection expense? If so, how was this taken care of?

MR. BOUTON:—The inspection part of the work has been decreased to some extent because we pay on the basis of accepted finished units. If any deductions are made, the men know that these come out of the entire group; therefore, if an operator tends to produce too much scrap, the other members in the group show him where he is making his errors or assist him to produce good work. I believe that in any group system, whether it is group-bonus or group piece-work, the amount of inspection is reduced.

QUESTION:—What average percentage of scrap is allowed?

MR. BOUTON:—Approximately 1 per cent average on machining operations.

QUESTION:—What percentage of your direct labor is piece-work?

MR. BOUTON:—Perhaps 90 per cent.

QUESTION:—What percentage above the day-rate does the average operator make on piece-work?

MR. BOUTON:—Painters and trimmers make considerably more than the day-rate. In the assembly department, it runs anywhere from 15 to 25 per cent over the day-rate. If 50 men are engaged in a group and one man is raised 50 cents per day, that reduces the earnings of the other members of the group approximately 1 cent per day. The revision of rates of one or two members from time to time does not change much the

of the other members of the group. However, such charges are justified for the reason that the [illegible] are raised are performing operations that require skill or fatiguing. Revision of rates after the price is set seldom occurs because, when the price is set, all hourly day-rates are adjusted likewise to suit the [illegible] of the various operations.

QUESTION:—Do you have to sell that idea to the group first?

MR. BOUTON:—No; we have never experienced any trouble along that line in adjusting rates within the group.

QUESTION:—What procedure do you follow in the group plan where, for instance, there are four men, and the man performing the last operation does poor work that necessitates the scrapping of the entire unit? Do you deduct from the pay of whole group?

MR. BOUTON:—Absolutely; inasmuch as the earnings of the group constitute collective effort, what one man scraps must be handled from the group standpoint.

QUESTION:—What deductions are made for tardiness?

MR. BOUTON:—If a man comes in 1 hr. late, he loses 1 hr. of his pro-rated earnings, but that is given to the other members in the group. The company does not receive any direct benefit from it, but some means of penalizing the man for non-attendance must be provided.

QUESTION:—Are speed experts placed in the group to increase production?

MR. BOUTON:—The regular operators assigned to a group are generally used. We do not resort to utility men or speed experts to set prices or to speed-up a group, unless the time-study observer recommends that other men be assigned to the group to obtain better production.

QUESTION:—Do you find cases of earnings running higher than was expected?

MR. BOUTON:—Sometimes, due to the group application of effort and cutting a few corners here and there, earnings have run slightly higher than the amount anticipated. That is common to all wage-incentive systems. It is expected that the group will produce as much work as possible, and some very clever time-saving methods are applied.

QUESTION:—Do you use the group system on inspection work?

MR. BOUTON:—In general, inspection is day-work. There is practically no piece-work on inspection operations.

QUESTION:—What provision is made for an absentee from a group?

MR. BOUTON:—None. If there are 10 men assigned regularly to the group and only 9 show up, they continue to produce the unit and their earnings are pro-rated among the 9 men. If several operators are absent, it would be necessary to add other men to the group.

QUESTION:—Does the group plan affect promotion?

MR. BOUTON:—Promotion is handled in the same manner as under any other system.

QUESTION:—How is the tool department paid?

MR. BOUTON:—On the day-work basis.

QUESTION:—Do the men have any voice in the selecting or hiring of the men to work in their respective groups?

MR. BOUTON:—If a man should be assigned to a group and, for some particular reason, the group objected to his being placed in that group, the men would take the matter up with the department foreman. If they had reasonable objections, the man would be assigned to other work and some other man would be substituted.

QUESTION:—What constitutes a unit?

MR. BOUTON:—Any part that can be machined by consecutive operations, or any number of small parts that can be assembled into one major part, is called a unit; for example, all machining operations on a front axle, the assembly of a complete engine, all the machining operations on a crankcase, or the assembly of a complete transmission.

QUESTION:—Do you find that the individual effort is destroyed in a group of 90 men?

MR. BOUTON:—The individual effort is practically the same in a large group as it is on straight piece-work. The men are all anxious to help one another. Whenever congestion occurs in one part of a group, the other men assist without any orders from the foreman.

QUESTION:—Are the guaranteed hourly-rates equal to or lower than the going rates for straight day-work?

MR. BOUTON:—They are lower than for straight day-work. If we have a day-work operation, the day-rate for the operator is naturally a little higher than it would be for an operator whose operation is piece-work.

QUESTION:—What operations can be grouped best?

MR. BOUTON:—That must be determined largely by the individual plant. Assembly work lends itself very readily to group piece-work; also many machine operations. For some small parts requiring only one or two operations, we have found straight piece-work better than group work. Some plants place in a group 8 or 10 machines that are working on entirely different parts. We have never done that; only the job itself carries the piece-work price.

QUESTION:—Is not a community of interest established by the group that has a tendency to unionize a shop?

MR. BOUTON:—That question has been brought up many times. We have not had a single argument with any group that has not been adjusted satisfactorily. The groups have never made any unreasonable demands upon the company since the plan has been in operation. We believe that our freedom from the difficulties indicated is due largely to the piece-work feature of the plan.

QUESTION:—Does your group system at any time take care of a labor shortage? How do the men react then?

MR. BOUTON:—The group workers' interest in their work has been the means of getting good labor into the group. Each individual group-worker may know of some man he would like to have in his group. Men have even gone to the employment department and asked permission to bring in such a man, knowing that we were short of labor on some operations. The system has been much better for the company than the straight piece-work system was.

QUESTION:—It is very seldom that we can expect 100-per cent quality. Do you provide a motive for producing quality?

MR. BOUTON:—No reward is given for quality other than the rate, with the penalty for scrap provided for.

QUESTION:—How do you prevent a foreman from showing favoritism to some friend or individual in a group?

MR. BOUTON:—We have not experienced much difficulty along that line. The matter is watched carefully. All rate-increases that go into effect pass through the hands of the production manager and others. If any evidence of favoritism were shown, either in the assignment of men to operations or about the rates, it would be observed very quickly by other members of the group and called to the attention of the production manager and the time-study department.

QUESTION:—How do you determine who is at fault

when deduction for scrap has to be made from the earnings of the group?

MR. BOUTON:—When the piece is inspected and the cause of the scrap is determined, we can trace it back directly to the man who performed the operation. The group then knows who is responsible. The men take the subject up with this member of the group and help him to improve his work or have another man put in his place.

PRESIDENT ALDEN:—Have you found this group plan effective in weeding out undesirables?

MR. BOUTON:—It has been very effective. Men who did not show very much activity or were careless and indifferent on the jobs were eliminated by the group itself.

PRESIDENT ALDEN:—That has been the experience of a corporation of which I know, wherever the management installed the group plan.

J. C. W. SMITH:—The Willys-Overland Co. has used straight piece-work for about 3 years. The prices are set from time studies. We follow out the principles Mr. Bouton has outlined except that, where it is necessary to work the men in a group, we divide the money between the men in the group according to the hours they work. The group operations are divided so that the skilled man earns his money by his skill and the less skilled operators earn their money by the exertions they put forth. Individual piece-prices are paid wherever practicable; group piece-prices are paid when necessary. We have straight piece-work in place of standard time, because we believe piece-work is direct, simple and easily understood. The men know that they will receive so much money for doing the operation each time it is performed. The defect in standard time, as we see it, is that, for the man to know how much money he will receive on pay-day, he must divide his actual time into the allowed time, which gives him his percentage of efficiency. By referring to the bonus table, he finds out what percentage of bonus he is paid for his efficiency and, by multiplying his day's wages by the percentage indicated in the bonus table, he arrives at the amount of money he will receive in addition to his day-work earnings. If two men working at a different day-rate on identical operations finish the same number of pieces in the same time, they will receive a different amount under standard time. Our company guarantees its approved piece-prices for the calendar year. We believe that 25 per cent of the increase in the efficiency in our plant in the last 2 years was due to the fact that the men knew and understood the guaranteed piece-price and realized that they would not be penalized for the efficiency they developed. Guaranteed prices are designated by letter prefixes on the piece-price schedule. For example, in X189, the X indicates that if a change in the operation is made, the change in the price will be in exact proportion to the time that it takes longer or less to do the operation, for the year 1923.

MR. BOUTON:—Mr. Smith's principal objection to the standard-time system is typical of many other systems. For example, if two operators were engaged on the same job and their hourly-rates were 60 and 65 cents respectively, and both operators finished the same number of pieces per day, the 65-cent operator's earnings would be more than those of the operator with the 60-cent rate; therefore, it is not equal reward for equal effort and, in addition, the cost department has a variation in cost and it is this cost that must be accumulated over a period of time to arrive at an average cost. Where several operations are necessary to complete one unit, it is not always possible to balance the operations so that each can be performed in the same length of time. Assuming that the first operation required 10 min., the second 8 min. and the third 6 min., it can be seen readily that the production of the 6-min. operation would be no more than that of the 10-min. operation; therefore, the 6-min. operation operator assists the operator on the first operation so as to maintain a balance of finished pieces, and this is where the efforts of group work are applied which would be impossible with individual effort or straight piece-work. Progressive assembly or progressive machining operations are performed more economically with the application of group piece-work. If all operations were in perfect balance, it would be possible to use straight piece-work. However, there is seldom if ever a job of five or more operations wherein all operations balance; and it is not feasible, owing to the production of each operation, to maintain an operator for each. The group plan fixes the number of men to be assigned according to the schedule of finished units. As explained previously, all of the group operations are combined into one, a price is set thereon and all members of the group participate in the group earnings according to their hourly-rates and the number of hours worked.

QUESTION:—In leather cutting, do you pay an incentive wage for saving leather?

MR. BOUTON:—Yes. The amount of leather saved or the number of square feet cut out of the hide determines the operator's earnings.

THE STANDARDIZATION OF METHODS OF APPLYING THE SCLEROSCOPE

BY A. F. SHORE

A STATEMENT is made of nine items suggested by the Iron and Steel Division of the Society for consideration with reference to securing greater uniformity in practice when making precision hardness-tests with the scleroscope. Plumbness of the instrument is an important factor and lateral vibrations have a bad effect; these are discussed and surface smoothness of the test-specimen is considered in relation to its effect on accuracy.

Other factors treated are the influence of metal-scale on scleroscope readings, the condition of the hammer diamond, and the effect of the mass of the test-specimen. Extreme under-weight specimens, inert and over-weight masses, the effect of hardness on mass and the effect of thickness of the test-specimen receive consideration, together with points concerning testing near test-specimen edges, the effect of curved surfaces and how test-specimens are held. A lengthy comparison between Brinell and scleroscope hardness-testing is made. The paper presents photographs and illustrative charts.

THE DISCUSSION

QUESTION:—Why do you use a plumb-rod instead of a spirit-level? Would not the spirit-level arrangement be more reliable in the hands of the average operator?

A. F. SHORE:—We think the plumb-rod is better for

[illegible] service. Sometimes, when you are not looking, you can hear it rattle. That is a warning that the spirit-level should not give.

QUESTION:—Is it not the universal practice to polish test-specimens before they are scleroscoped?

MR. SHORE:—Nothing is gained by polishing the test-specimen with very fine emery paper or by buffing. An emery paper or wheel or a file of medium grade is good enough for all purposes.

QUESTION:—What of air-operating devices for the scleroscope to prevent the cramping of the operator's hand, because of the large number of times he must open and close it?

MR. SHORE:—Such devices are in use, but we have not undertaken to manufacture them thus far as very little demand is made for them.

QUESTION:—Is it necessary to clamp parts, such as the wristpin, in the vise?

MR. SHORE:—No, if a slight allowance can be made for loss due to imperfect under-support and for hollowness.

QUESTION:—What is the best method of testing flat wire of 0.002 to 0.020-in. thickness?

MR. SHORE:—Clamp it flat on the scleroscope anvil with possibly a grooved guide, but it may be flat at the bottom.

QUESTION:—Does a change in the quality of the atmosphere cause any difference in scleroscope readings?

MR. SHORE:—We doubt if it does, unless actual moisture in the form of dew accumulates in the glass tube.

QUESTION:—What factor can be divided into the Brinell hardness reading to obtain the relative scleroscope reading?

MR. SHORE:—That is stated on a chart that we supply. No single factor can be used except at a particular range of the hardness scale.

QUESTION:—Do weather conditions affect the calibration of the Model-C scleroscope?

MR. SHORE:—It requires actual free-moisture, such as the formation of dew particles, in the glass tube.

QUESTION:—How can the hardness of two cylinder-blocks be determined when the scleroscope and the Brinell readings are approximately the same, yet one can be machined easily and the other is too hard to machine?

MR. SHORE:—If there is a difference in the resistance to machining, except possibly for a thin film of glass-hard scale, both methods will indicate such a condition in terms of hardness.

QUESTION:—In testing carbon blocks, of hardness ranging from 60 to 85, a difference of 10 to 15 per cent occurs between different instruments under identical conditions, although the same instruments give identical readings on steel test-blocks. Is there any explanation?

MR. SHORE:—For testing carbon, the penetration is often so deep that the diamond has to be fashioned especially for that purpose, with the sides of the cone frustrum also standardized.

FACTORS GOVERNING "OUT-OF-ROUNDNESS" MEASUREMENT

BY A. H. FRAUENTHAL

IT is stated that an out-of-round surface having an even number of high-spots requires a checking instrument that has opposed measuring points; and that, if the number of high-spots on the surface is uneven, an instrument having three-point contact, and one of the points of contact located on the center line between the other two, is necessary. Concerning the use of the three-point method, for close work, the angle between the three points of contact must be selected according to the number of high-spots.

Divisions of the subject include types of out-of-roundness and those peculiar to certain machines, the three-point measuring system, errors of the V-block method, use of the V-block for elliptical objects, other methods of checking elliptical forms and indicator-reading correction. Three items for instrument improvement are suggested to manufacturers.

THE DISCUSSION

QUESTION:—What limit of out-of-roundness is allowable for wristpins?

A. H. FRAUENTHAL:—It is generally conceded to be 0.0002 in. Some plants demand that wristpins be absolutely round, but they mean by "absolutely round" 0.0002 or 0.0003 in. as a limit for out-of-roundness. We use a limit of 0.0002 in. ourselves and we have not found that 0.0003 in. gives us very bad results. In the higher-priced cars they like to lap a wristpin and they claim they get it closer than 0.0002 in., but I do not honestly know whether we can detect any appreciable difference in the operation of the engine with either one or the other.

QUESTION:—Is not the slight out-of-roundness obtained by present production methods practically negligible in automobile work?

MR. FRAUENTHAL:—It probably is if the machine is always running just right and the type of machine is such that it does not produce much out-of-roundness. However, a centerless grinding-machine produces very accurate work, provided the operations previous to the last grinding or finish-grinding have been done very carefully, so that the amount of stock to be removed is very small. On the other hand, if you crowd a machine of that type, it will most certainly produce out-of-roundness regardless of how tight all the moving parts of the machine are, the good care taken of it generally and the care given it by the operator.

QUESTION:—What amount of out-of-roundness have you found existing in crankshafts and in wristpins that has escaped detection?

MR. FRAUENTHAL:—I believe that no out-of-roundness on crankshafts has escaped us except that beyond the limits of the use of the micrometer. A good inspector can detect out-of-roundness of 0.0001 in. without very much trouble. Any amount of out-of-roundness might escape attention on a wristpin ground on a centerless grinding-machine if a three-point measuring-method is not used.

QUESTION:—Which do you find best for accuracy, the centerless grinding-machine or one that has centers?

MR. FRAUENTHAL:—We found that equally accurate work can be done on both types of machine. For some work, no doubt, the centerless grinding-machine is considerably more rapid than the usual type that employs centers. However, the centerless machine seems to give us somewhat more trouble, probably due to the fact that the operations preceding the last grinding are not done as carefully as is required for this type of machine.

The Packard Single-Eight

By J. G. VINCENT[1] *assisted by* W. R. GRISWOLD[2]

CLEVELAND SECTION PAPER

Illustrated with DRAWINGS

LIMITATIONS regarding space available prevented the publication in the October, 1923, issue of THE JOURNAL of the mathematical analyses referred to in the paper on The Packard Single-Eight. These were presented by the author in two appendices, which are printed herewith.

ABSTRACT

STATING the fundamental characteristics of the modern motor car under the headings of performance, safety, economy, comfort and taste, the author defines these terms and discusses each basic group. The specifications of the car in which the single-eight engine is installed are given, and the reasons governing the decision to use an eight-cylinder-in-line engine are enumerated.

Following a somewhat lengthy discussion of the components of engine performance, the design of the engine is given detailed consideration under its divisions of crankshaft design and the methods employed, gas distribution, the operation of the fuelizer, cylinders, valve gear and the arrangement of the accessories. Transmission design and the wearing quality of gears receive similar treatment.

Brakes and steering are subjects that are treated at some length, arguments being presented in favor of four-wheel brakes and reasons given for their adoption, together with a discussion of their effect on steering ability and of the mechanics of brake construction. Comfortable steering, axle construction, steering-gear efficiency and axle noise are other subjects that are considered in detail. The paper is illustrated profusely and pertinent tabular data are included.

APPENDIX 1

ENGINE BALANCE[3]

On account of the acceleration of the reciprocating and rotating parts of the engine, dynamic forces are set up which, when unbalanced, produce either periodic displacement or simply vibration of the engine. A body of mass m acted on by a force F will have imparted to it an acceleration a and the relation can be expressed by

$$F = ma \tag{4}$$

If the weight of the body is W pounds, the mass will be

$$m = W/g \tag{5}$$

in which g equals the acceleration due to gravity, or 32.2 ft. per sec. per sec. Therefore, equation (4) becomes

$$F = (W/g)a \tag{6}$$

To find the acceleration of the piston, it is necessary to determine the piston travel and its velocity in terms of the angular motion of the crankshaft.

Piston Travel.—Referring to Fig. 28, we have, for piston travel in terms of the crank angle,

$$S = L + R - (R\cos\Theta + L\cos\phi) \tag{7}$$

$$= L + R - R\cos\Theta - L\,(1 - n^2\sin^2\Theta)^{\frac{1}{2}} \tag{8}$$

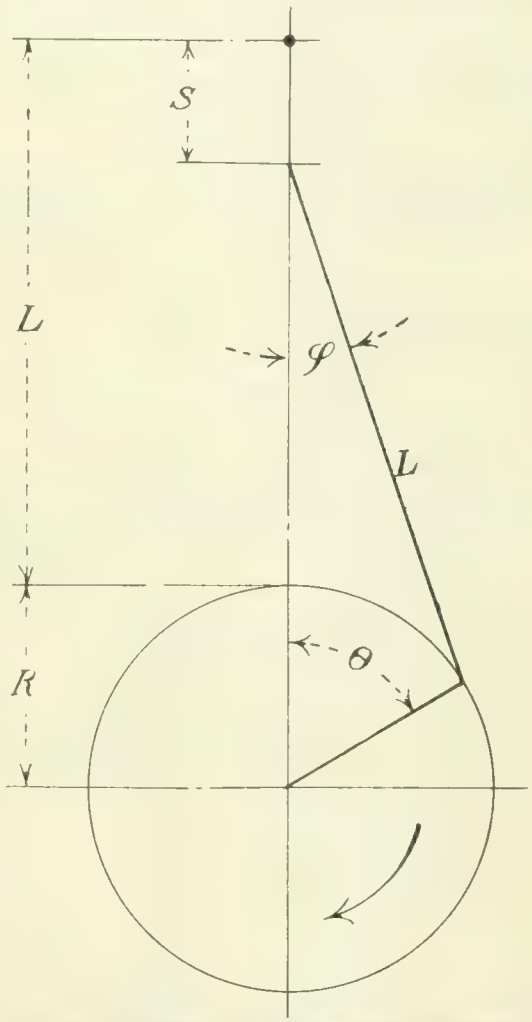


FIG. 28.—DIAGRAM OF THE RELATION OF PISTON TRAVEL, VELOCITY AND ACCELERATION IN A SIMPLE ENGINE

$$= L\,[1 + n - n\cos\Theta - (1 - n^2\sin^2\Theta)^{\frac{1}{2}}] \tag{9}$$

$$= L\,[1 + n - n\cos\Theta - (1 - \tfrac{n^2}{2}\sin^2\Theta - \tfrac{n^4}{8}\sin^4\Theta - \tfrac{n^6}{16}\sin^6\Theta \ldots \text{etc.})] \tag{10}$$

where

Θ = the crank angle
ϕ = the connecting-rod angle
S = the piston travel in terms of the crank angle in feet.
L = the length of the connecting-rod in feet
R = the length of the crank, or "throw" in feet
n = the ratio of the crank and connecting-rod (R/L)

But

$$\sin^2\Theta = \frac{1 - \cos 2\Theta}{2} \tag{11}$$

$$\sin^4\Theta = \frac{3}{8} - \frac{1}{2}\cos 2\Theta + \frac{1}{8}\cos 4\Theta \tag{12}$$

$$\sin^6\Theta = \frac{5}{16} - \frac{15}{32}\cos 2\Theta + \frac{3}{16}\cos 4\Theta - \frac{1}{32}\cos 6\Theta \tag{13}$$

[1] M.S.A.E.—Vice-President of engineering, Packard Motor Car Co., Detroit.

[2] M.S.A.E.—Engineer in charge of analysis of design, Packard Motor Car Co., Detroit.

[3] Figs. 1 to 27 and Equations (1) to (3) appear in the paper, as printed in the October, 1923, issue of THE JOURNAL, p. 257.

Substituting in equation (10) and reducing

$$\quad + \cos 6\theta] \qquad (14)$$

Since the value of k becomes smaller and smaller, all terms beyond the sixth term may be dropped.

Piston Velocity.—Denoting this by v, we have the relation

$$(15)$$

Assuming the angular velocity $d\theta/dt$ to be uniform and equal to ω, we have

$$= -r\omega(\sin\theta + 2k\sin 2\theta - 4k^3\sin 4\theta + 6k^5\sin 6\theta) \qquad (16)$$

Piston Acceleration.—This is denoted by a, and we have the expressions

$$(17)$$

$$(18)$$

Acceleration Force for One Cylinder

In considering the force of acceleration for one cylinder we have

$$F = \qquad (19)$$

Then the force F_a, due to the acceleration of the reciprocating parts for one cylinder, is

$$= \frac{W}{g} r\omega^2(\cos\theta + 4k^3\cos 2\theta - 16k^5\cos 4\theta + 36k^7\cos 6\theta) \qquad (20)$$

Let $K = \frac{W}{g} r\omega^2$. Then, equation (20) becomes

$$= K(\cos\theta + 4k^3\cos 2\theta - 16k^5\cos 4\theta + 36k^7\cos 6\theta) \qquad (21)$$

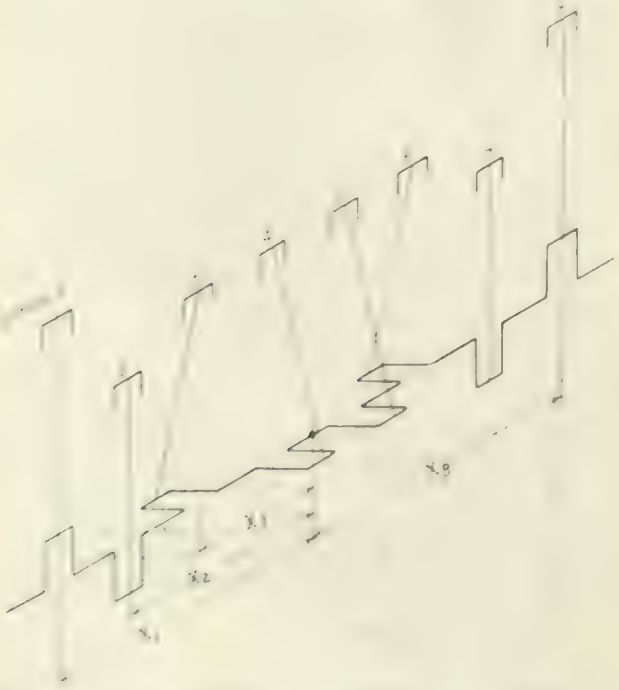


Fig. [illegible] Assembly Diagram of the Piston and Crankshaft Used in the Packard Eight Cylinder Engine

The General Case of Engine Balance for Multi-Cylinder Engines

For an engine having any arrangement of the cylinders and crank-throws, the summation of the horizontal and the vertical components, and the summation of the moments in the horizontal and the vertical planes, can be determined separately. If the cylinders make any angle β with the vertical plane, we have, for the summation of the horizontal, h, and vertical, v, forces

$$\Sigma F_h = \Sigma[K(n\cos\theta + 4k\cos 2\theta - 16k\cos 4\theta + 36k\cos 6\theta)(\sin\beta)] \qquad (22)$$

$$\Sigma F_v = \Sigma[K(n\cos\theta + 4k\cos 2\theta - 16k\cos 4\theta + 36k\cos 6\theta)(\cos\beta)] \qquad (23)$$

If x denotes the distance along the axis of the crankshaft, as in Fig. 29, we have, for the summation of the moments, M, in the horizontal, h, and vertical, v, planes

$$\Sigma M_h = \Sigma[K(n\cos\theta + 4k\cos 2\theta - 16k\cos 4\theta + 36k\cos 6\theta)(\sin\beta)x] \qquad (24)$$

$$\Sigma M_v = \Sigma[K(n\cos\theta + 4k\cos 2\theta - 16k\cos 4\theta + 36k\cos 6\theta)(\cos\beta)x] \qquad (25)$$

For the condition of perfect balance ΣF_h, ΣF_v, ΣM_h and ΣM_v must be equal to zero.

Balance of the Single-Eight Engine

In the Packard single-eight engine, the angle β that the cylinders make with the vertical plane is equal to zero; hence when $\beta = 0$, we have $\Sigma F_h = 0$ and $\Sigma M_h = 0$. Since $\cos\Theta = 1$ and the reciprocating masses are equal, we have

$$\Sigma F_v = K[\Sigma(n\cos\theta) + \Sigma(4k\cos 2\theta) - \Sigma(16k\cos 4\theta) + \Sigma(36k\cos 6\theta)] \qquad (26)$$

Let

$$\Sigma F_1 = \Sigma(n\cos\theta)$$
$$\Sigma F_2 = \Sigma(n\cos 2\theta)$$

and the like for the forces due to the acceleration of the reciprocating parts for cylinders Nos. 1 to 8, and let $\theta_1, \theta_2, \ldots \theta_8$ denote the crank angle for cylinders Nos. 1 to 8 respectively. Then,

$$\begin{aligned}
\theta_1 &= \theta \\
\theta_2 &= \theta_1 \pm 180 = \theta \pm 180 \\
\theta_3 &= \theta_1 + 90 = \theta + 90 \\
\theta_4 &= \theta_1 - 90 = \theta - 90 \\
\theta_5 &= \theta_1 - 90 = \theta - 90 \\
\theta_6 &= \theta_1 - 90 = \theta - 90 \\
\theta_7 &= \theta_1 + 180 = \theta \pm 180 \\
\theta_8 &= \theta_1 = \theta
\end{aligned}$$

Then, the primary forces for these cylinders are

$$\Sigma F_1 = Kn\begin{vmatrix} \cos\theta_1 \\ \cos\theta_2 \\ \cos\theta_3 \\ \cos\theta_4 \\ \cos\theta_5 \\ \cos\theta_6 \\ \cos\theta_7 \\ \cos\theta_8 \end{vmatrix} = Kn\begin{vmatrix} \cos\theta \\ \cos(\theta + 180) \\ \cos(\theta + 90) \\ \cos(\theta - 90) \\ \cos(\theta - 90) \\ \cos(\theta + 90) \\ \cos(\theta + 180) \\ \cos\theta \end{vmatrix} = Kn\begin{vmatrix} \cos\theta \\ \cos\theta \\ -\sin\theta \\ \sin\theta \\ \sin\theta \\ -\sin\theta \\ -\cos\theta \\ \cos\theta \end{vmatrix} \qquad (27)$$

Therefore

$$\Sigma F_1 = Kn\begin{bmatrix} 2\cos\theta - 2\cos\theta \\ + \\ 2\sin\theta - 2\sin\theta \end{bmatrix} = 0 \qquad (28)$$

Equation (28) shows that the total of the primary forces for any crank angle and in every plane is equal to zero; that is, the forces are balanced completely.

The total secondary force for all eight cylinders is

$$\Sigma F_{a_2} = 4Kk_2 \begin{bmatrix} \cos 2\theta_1 \\ \cos 2\theta_2 \\ \cos 2\theta_3 \\ \cos 2\theta_4 \\ \cos 2\theta \\ \cos 2\theta_6 \\ \cos 2\theta_7 \\ \cos 2\theta_8 \end{bmatrix}$$

$$= 4Kk_2 \begin{bmatrix} \cos 2\theta \\ \cos 2(\theta \pm 180) \\ \cos 2(\theta + 90) \\ \cos 2(\theta - 90) \\ \cos 2(\theta - 90) \\ \cos 2(\theta + 90) \\ \cos 2(\theta \pm 180) \\ \cos 2\theta \end{bmatrix}$$

$$= 4Kk_2 \begin{bmatrix} \cos 2\theta \\ \cos 2\theta \\ -\cos 2\theta \\ -\cos 2\theta \\ -\cos 2\theta \\ -\cos 2\theta \\ \cos 2\theta \\ \cos 2\theta \end{bmatrix} \quad (29)$$

Therefore, we have

$$\Sigma F_{a_2} = 4Kk_2 (4\cos 2\theta - 4\cos 2\theta) = 0 \quad (30)$$

which shows that the secondary forces are balanced completely.

The fourth-order harmonic for all eight cylinders is

$$\Sigma F_{a_4} = 16Kk_4 \begin{bmatrix} -\cos 4\theta_1 \\ -\cos 4\theta_2 \\ -\cos 4\theta_3 \\ -\cos 4\theta_4 \\ -\cos 4\theta_5 \\ -\cos 4\theta_6 \\ -\cos 4\theta_7 \\ -\cos 4\theta_8 \end{bmatrix}$$

$$= 16Kk_4 \begin{bmatrix} -\cos 4\theta \\ -\cos 4(\theta \pm 180) \\ -\cos 4(\theta + 90) \\ -\cos 4(\theta - 90) \\ -\cos 4(\theta - 90) \\ -\cos 4(\theta + 90) \\ -\cos 4(\theta \pm 180) \\ -\cos 4\theta \end{bmatrix}$$

$$= 16Kk_4 \begin{bmatrix} -\cos 4\theta \\ -\cos 4\theta \\ -\cos 4\theta \\ -\cos 4\theta \\ -\cos 4\theta \\ -\cos 4\theta \\ -\cos 4\theta \\ -\cos 4\theta \end{bmatrix} \quad (31)$$

Therefore

$$\Sigma F_{a_4} = -128 Kk_4 \cos 4\theta \quad (32)$$

Equations (31) and (32) show that the fourth-order harmonics synchronize in the vertical plane.

The sixth-order harmonic for all eight cylinders is

$$\Sigma F_{a_6} = 36Kk_6 \begin{bmatrix} \cos 6\theta_1 \\ \cos 6\theta_2 \\ \cos 6\theta_3 \\ \cos 6\theta_4 \\ \cos 6\theta_5 \\ \cos 6\theta_6 \\ \cos 6\theta_7 \\ \cos 6\theta_8 \end{bmatrix}$$

$$= 36Kk_6 \begin{bmatrix} \cos 6\theta \\ \cos 6(\theta \pm 180) \\ \cos 6(\theta + 90) \\ \cos 6(\theta - 90) \\ \cos 6(\theta - 90) \\ \cos 6(\theta + 90) \\ \cos 6(\theta \pm 180) \\ \cos 6\theta \end{bmatrix}$$

$$= 36Kk_6 \begin{bmatrix} \cos 6\theta \\ \cos 6\theta \\ -\cos 6\theta \\ -\cos 6\theta \\ -\cos 6\theta \\ -\cos 6\theta \\ \cos 6\theta \\ \cos 6\theta \end{bmatrix} \quad (33)$$

Therefore

$$\Sigma F_{a_6} = 36 Kk_6 (4\cos 6\theta - 4\cos 6\theta) = 0 \quad (34)$$

Hence, the resultant of the forces in the vertical plane is

$$\Sigma F_{av} = -128 Kk_4 \cos 4\theta \quad (35)$$

and the resultant of the forces in the horizontal plane is

$$\Sigma F_{ah} = 0 \quad (36)$$

Rocking Couples

Primary Forces.—By making use of equations (24) and (25), we obtain

$$\Sigma M_{v_1} = Kn \begin{bmatrix} x_1 \cos\theta \\ -x_2 \cos\theta \\ -x_3 \sin\theta \\ x_4 \sin\theta \\ x_5 \sin\theta \\ -x_6 \sin\theta \\ -x_7 \cos\theta \\ x_8 \cos\theta \end{bmatrix}$$

$$\Sigma M_{v_1} = Kn \begin{bmatrix} (x_1 - x_8)\cos\theta - (x_2 + x_7)\cos\theta \\ + \\ (x_4 + x_5)\sin\theta - (x_3 + x_6)\sin\theta \end{bmatrix}$$

But, for a symmetrical arrangement of the crank-throws, having the same phase, along the axis of the crankshaft and relative to the middle point between the end cylinders, we have

$$(x_1 - x_8) = (x_2 - x_7) = 0$$
$$(x_4 + x_5) = (x_3 + x_6) = 0$$

Therefore,

$$\Sigma M_{v_1} = 0$$

Secondary Forces.—By making use of equations (24) and (25), we obtain

$$\Sigma M_{v_2} = 4Kk \begin{bmatrix} x_1 \cos 2\theta \\ x_2 \cos 2\theta \\ -x_3 \cos 2\theta \\ -x_4 \cos 2\theta \\ -x_5 \cos 2\theta \\ -x_6 \cos 2\theta \\ x_7 \cos 2\theta \\ x_8 \cos 2\theta \end{bmatrix}$$

$$\Sigma M_{v_2} = -\cos 2\theta (x_1 - x_2 + x_3 - x_4) - \cos 2\theta (x_5 - x_6 + x_7 - x_8)$$

But, for a crankshaft in which the cranks in the same phase relation are longitudinally placed relative to the middle of its length, we have

$$(x_1 - x_2 + x_3 - x_4) = (x_5 - x_6 + x_7 - x_8) = 0$$

Therefore,

$$\Sigma M_{v_2} = 0$$

Fourth-Order Forces.—Treating the fourth-order forces in exactly the same manner in which the secondary forces were treated, we find that

$$\Sigma M_{v_4} = 0$$

Sixth-Order Forces.—Similar treatment of the sixth-order forces gives

$$\Sigma M_{v_6} = 0$$

Therefore, the engine is entirely free from rocking couples, since

$$\Sigma M_h = 0 \text{ and } \Sigma M_v = 0$$

Total Unbalanced Forces

The total of the unbalanced forces for the Packard single-eight engine amounts to only 32 lb. at 3000 r.p.m. This is equal to the unbalanced primary force produced

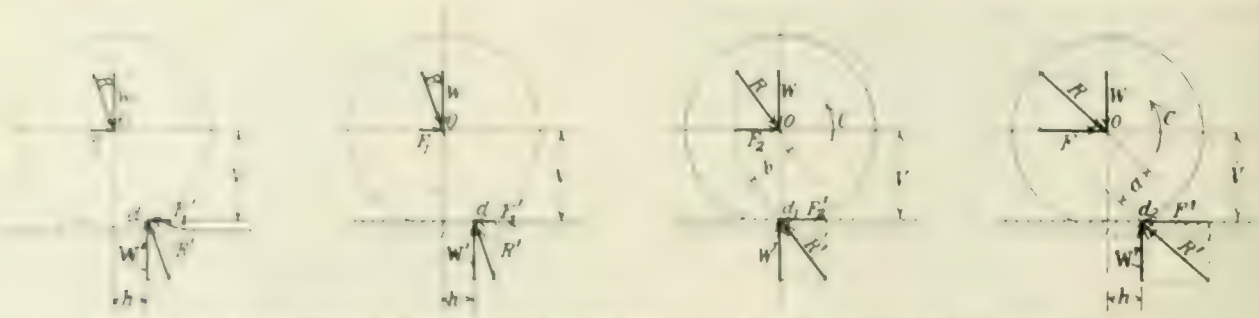


FIG. [illegible]—DIAGRAMS OF THE VARIOUS FORCES INVOLVED IN THE ROTATION OF A WHEEL

an accumulated difference in weight of all the piston assemblies of only 2 oz., which is a tolerance that would be utterly impracticable to work to in manufacturing. Even then, the difference in the amplitude of vibration would be only 1/36 as great, because the frequency of the sixth-order forces is six times the primary frequency. There can be no question of the insignificance of such a slight unbalance.

APPENDIX 2

DERIVATION OF THE FORMULA FOR TURNING MOMENT ABOUT THE STEERING-PIVOT

For an analysis of the forces acting on a wheel and overcoming rolling resistance, we refer to the left half of Fig. 30 and to the text of the paper under Fundamental Requirements of Brakes and Steering[3]. For a condition of equilibrium, we find

$$F = F' = 0$$
$$W + W' = 0$$

Therefore,

$$F = W(h - V)$$

But, r very nearly equals V; hence, we have

$$F = W(h - r) \qquad (37)$$

For an analysis of the forces on a wheel locked by brakes and sliding with uniform motion, we refer to the [illegible] central drawing in Fig. 30 and to the text of the paper under Forces for Locked Wheels[3]. From the definition of sliding friction, we have, using f to represent the coefficient,

$$F_1 = fW \qquad (38)$$

Then, we have $F - F' = 0$, or $\Sigma F = 0$; and also, $W + W' = 0$ or $\Sigma V = 0$. But, taking moments about O, we have a couple $C'' = Fr$, which, to satisfy the condition for equilibrium, must be resisted by an equal and opposite couple, hence $C + C'' = 0$, or $C = -C''$, this couple is necessary to restrain the wheel against rotation, in this case due to the action of front-wheel brakes and to friction at the bearings.

For an Analysis for Mixed Resistance, we refer to the drawing at the extreme right of Fig. 30 and to the text of the paper. For the condition of equilibrium, we have

$$C = FV - Wh$$

But, $h = F_1V_1/W$ and V very nearly equals r; hence, $F_1 = W(h - r)$. Let $F = F_1 + F_2$, where F_1 equals rolling resistance. Then, since $F = W(h - r)$, we have

$$C = (F_1 + F_2)r - Wh$$
$$= Wh - F_1r - Wh$$
$$= F_2r$$
$$= (F - F_1)r \qquad (39)$$

If we denote the coefficient of static friction by f_0, then F_2 becomes a maximum when $F_2 = f_0W$, and we have

$$C = f_0Wr \qquad (40)$$

However, the couple C may have any value from zero

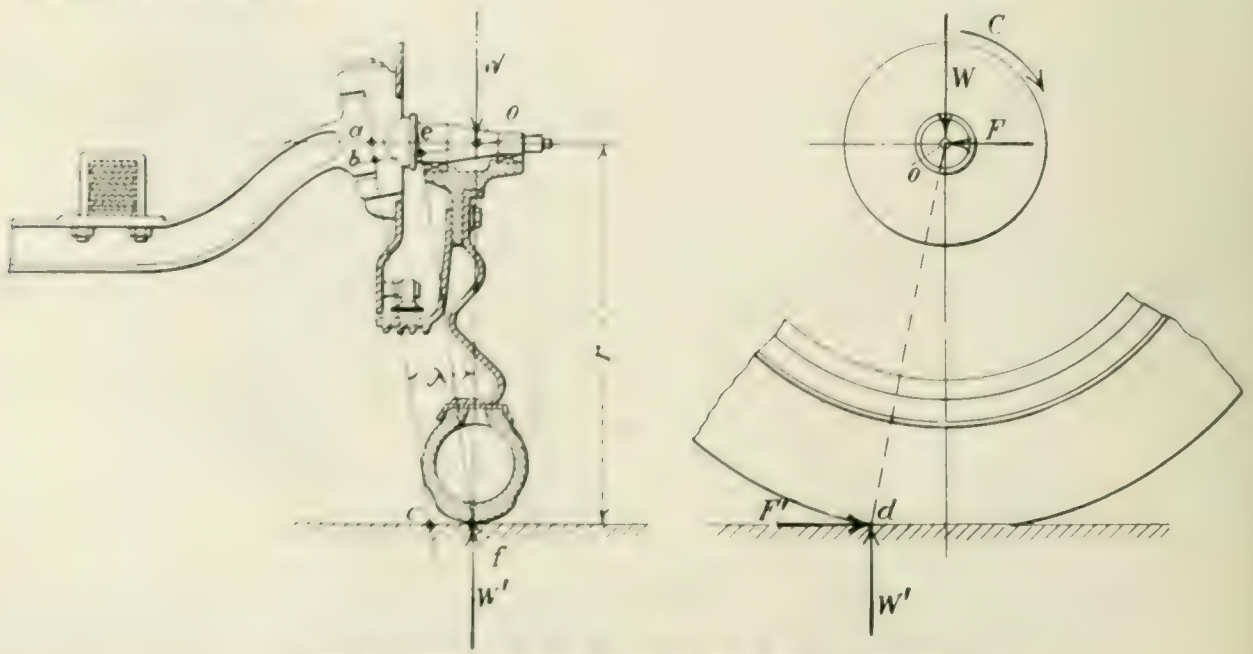


FIG. 31—DIAGRAM OF THE FORCES IN THE STEERING-KNUCKLE

to $f_0 Wr$, depending only upon the friction at the bearings and the frictional moment exerted by the brakes.

Forces Acting on the Steering-Knuckle

For a general analysis of the forces acting on the steering-knuckle, we refer to the left-hand portion of Fig. 31. Let

λ = the angle made by the center plane of the wheel and the steering-pivot axis
m = the ground intercept of the steering-pivot axis and the center of contact area
F = the horizontal force required to overcome the total resistance
F' = the horizontal force required to overcome the rolling resistance
W = the weight on the wheel
C = the reacting couple about the axis of rotation of the wheel
r = the radius of the wheel

The resistance F' and the reaction of the weight W' act at the point d in the right-hand portion of Fig. 31. Referring to the upper portion of Fig. 32, the weight on the wheel acts through the point O of the steering-knuckle; also, the force F acts through the point O in the center plane of the wheel.

Referring first to the right and then to the left-hand portion of Fig. 31, let the distances

$$of = r$$
$$od = a$$
$$ob = b$$
$$oe = c$$
$$cf = m$$
$$be = e$$

Then,

$$b = a \cos \lambda$$
$$= c - e$$
$$= r \sin \lambda - m \cos \lambda$$

The lower portion of Fig. 32 represents the steering-knuckle with the wheel removed and the reactions at O replaced by the actions W, F and C, equal and opposite.

We can represent the couple C by its moment vector M. Then, resolving the moment axis M into its components M_n and M_t as in the lower portion of Fig. 32, respectively normal and parallel to the steering-pivot axis, we have

$$M_n = M \cos \lambda$$
$$M_t = M \sin \lambda$$

The moment vector M_n, being normal to the steering-pivot axis, exerts no rotative tendency about the pivot axis, but the tangential component M_t exerts a tendency of rotation which must be reacted by the steering-gear or, if it is balanced by the wheel on the opposite side of the car, it induces stresses in the tie-rod and the steering-arms.

The force F and its reaction at the steering-pivot axis forms, about the pivot axis, the couple $M_h = Fb$, in Fig. 32, which is opposite in its tendency with reference to M_t and is represented by the moment vector M_h. The resultant moment M_r is the algebraic sum of M_h and M_t, and we have

$$M_r = M_h + M_t$$

But,

$$M_h = F (r \sin \lambda + m \cos \lambda)$$
$$M_t = -M \sin \lambda = -(F - F_1) r \sin \lambda$$

Then,

$$M_r = F (r \sin \lambda + m \cos \lambda) - (F - F_1) r \sin \lambda$$

Hence,

$$M_r = F m \cos \lambda + F_1 r \sin \lambda \qquad (41)$$

Equation (41) is the general equation for the net value of the couple C, due to the action of the total resistance tending to rotate the steering-knuckle about the steering-pivot axis.

Center-Point Steering

In center-point steering-design, the steering-pivot axis, when produced or extended, intersects the ground in the center plane of the wheel. Therefore, the distance cf in Fig. 31 becomes zero. Therefore, $m = 0$ and the first quantity in the right-hand member of equation (41), $Fm \cos \lambda = 0$. Hence

$$M_r = F_1 r \sin \lambda \qquad (42)$$

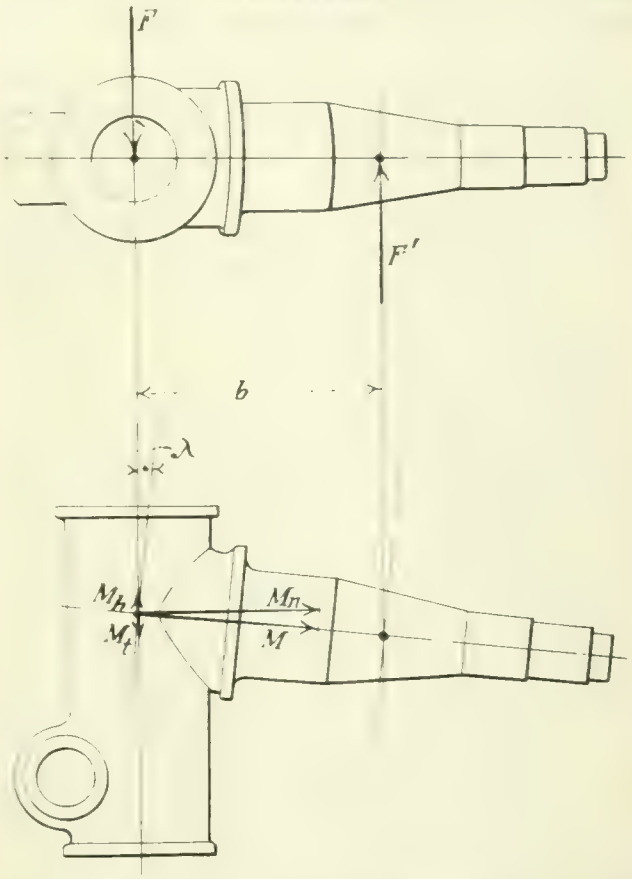


Fig. 32 Another Diagram of the Forces Acting on the Steering-Knuckle

In the equation (42), we find that the only resistance affecting the turning couple is F_1, which is the rolling resistance.

Conclusions

The conclusions drawn from this proof are enumerated as follows:

(1) The steering-linkage and steering-gear are not subjected to stress because of the action of the front-wheel brakes

(2) Steering is in no way affected by the action of the brakes. This is particularly important for, if this were not true, in case of a quick stop, if one wheel lost its traction the driving wheel would be given a strong wrench that probably would cause the driver to lose control of the car

(3) Maneuverability in parking a car, or on grades where brakes are required, is not affected appreciably when the brakes are applied. This makes it easier to maneuver the car in close or tight places

THE DISCUSSION

QUESTION:—Are the front-wheel brakes used only as a service brake?

MR. VINCENT:—We felt that all the braking effort that reasonably could be had was wanted in the service brake since these are the real emergency brakes, the [illegible] brake being nothing but a standing brake. In a car that has ability to accelerate rapidly and weighs considerable, the maximum braking effectiveness should be furnished obviously. It cannot be had on two wheels. Also in distributing the braking effort over four wheels wear is reduced greatly and the frequency of adjustment is decreased. In the Packard layout the rear-wheel brakes are also used for the standing brake, but they are operated through an independent mechanism.

QUESTION:—Is the pressure per square inch on the front-wheel brake-linings about the same as on the rear-wheel brake-linings?

MR. VINCENT:—The ratio of the pressures is as 45 on the front is to 55 on the rear.

QUESTION:—Do the front-wheel or the rear-wheel brakes accomplish the maximum braking? Are the rear-wheel brakes brought into play first and are the front wheels not effective until the rear wheels have begun to grip the road?

MR. VINCENT:—The front and the rear brakes go on practically at the same time.

QUESTION:—What rate of retardation do you secure at 15, 25, and 35 m.p.h.?

MR. VINCENT:—I think that our maximum rate of retardation is nearly 20 ft. per sec. per sec. According to my recollection, under ideal conditions I have stopped from a speed of 60 m.p.h. in 4.5 sec. in a little less than 200 ft.

QUESTION:—Is that practically the same stopping ability as with rear-wheel brakes alone?

MR. VINCENT:—It is a very much greater stopping ability. One of the things that impresses me about the action of these brakes is that, when applied hard at high speed, the car does not tend to jump around. I realize that some rear-wheel brakes are better than others, and it may be that some cars equipped with rear-wheel brakes alone can withstand having them jammed on at a car speed of 60 m.p.h. without causing the car to do anything except slow down smoothly; but, to say the least, that is difficult to accomplish. I think it is possible to slow down a big car fast with four-wheel brakes in a way that cannot be done with two-wheel brakes. I want you all to understand me clearly. I am not "sold" by any manner of means on the belief that all cars ought to have four-wheel brakes. I think that we must learn much about them. We have introduced them on our expensive car because we felt that we could get the money into them that was needed to build them right. I do not know just how cheaply we can make four-wheel brakes and still have them perfectly satisfactory. I think none of us knows. I am much interested in them. I think they are coming into general use, but I am not at all certain that they are going to be used on all sizes of car. It will not surprise me if we are still discussing this question 10 years from now.

QUESTION:—How do four-wheel brakes compare with two-wheel brakes under abnormal conditions, such as on wet, greasy road?

MR. VINCENT:—Such road conditions show-up the four-wheel brakes to their greatest advantage. I was very much surprised during winter driving in mountainous country to find that I could stop when a reasonable amount of snow was on the road almost as quickly as I would stop ordinarily on dry pavement. That should have been mentioned in the paper.

We did not make the brake leverage such as to produce what might be called "sensational" brakes. I do not believe in them or in sensational brake-exhibitions. Only very rarely does a person want to make a sensational stop; then, as was stated in the paper, a person has unusual power at his command and will apply the brakes much harder than normally. The four-wheel brakes are not intended to make sensational stops, but it is true that one can stop almost as quickly on slippery or wet pavement as one would stop ordinarily on dry pavement. I have never skidded yet except when I deliberately tried to skid when going around a turn.

QUESTION:—What is your opinion in regard to using a propeller-shaft brake as a service brake?

MR. VINCENT:—I do not favor using a propeller-shaft brake for general service. Propeller-shaft brakes serve satisfactorily for the standing brake when used in conjunction with four-wheel brakes. In the hands of the average owner, the hand-operated propeller-shaft brake is not used often in ordinary service conditions. Very satisfactory four-wheel brakes can be built for the same money as a practical propeller-shaft brake having sufficient strength provided in the axle to carry the braking loads.

QUESTION:—Have your investigations shown the necessity for the release of the outside front-wheel brake when the car is rounding a turn?

MR. VINCENT:—No. I claim that to be wrong absolutely. I defy anybody to show me how it will do any good.

QUESTION:—When descending a hill steep enough to require sufficient brake pressure to lock the wheels and approaching a sharp hairpin turn at the bottom of the hill, would locked front wheels have a tendency to hold the car to a straight course and cause it to leave the road at the turn?

MR. VINCENT:—To begin with, if the brake adjustment is correct, the rear wheels must become locked before the front wheels do and, if the car had gained such momentum that it was necessary to lock the wheels to stop it, this hardly could be considered rational driving. Certainly, if the full effect of four brakes is required to stop the car, it is evident at once that three brakes or only two brakes on the rear wheels would result in the car leaving the road. If the four-wheel brakes are good and the car is driven reasonably, it ought to be able to stop before reaching the turn.

QUESTION:—Has any investigation been made to determine the effect on the springs when four-wheel brakes are applied?

MR. VINCENT:—Much investigation has been necessary in connection with the front springs. However, when the springs are designed properly, they should not be affected to a degree that will have anything to do with the steering. The Hotchkiss drive will develop chatter if its linkages are not designed properly. We can do the same thing with front-wheel brakes. We must study our geometry. I think it is proper design to have the front-wheel brakes tend slightly to unwind the brake. By this I mean that if the brake is applied hard and the car slows-down quickly, the brakes should unwind a little rather than wind-up. If they wind-up, some trouble in the form of chatter is encountered. If the brakes are put on hard and the action tends to put them on still harder, that will be a very severe brake and, in the case of the wheel being thrown off the road by a stone, rut or crossing, the wheel will become locked while in the air and when it comes down it will catch, release, jump in the air again and cause a very violent chatter. I have

experienced that in the experimental stages. We have to design the linkages so that we will not run into that situation. Of course, we do not want to have the brakes unwind very much, because that would detract from the braking effort too much. On the other hand, if we happen to put the brakes on when we are backing-up, we would get the chatter if the action were too great. The action should be practically zero, of course.

QUESTION:—That is caused by the weight of the car piling-up on the front springs, is it not?

MR. VINCENT:—Yes, and by the deflection of the springs that allows the axle to twist a little.

QUESTION:—Has any tendency been noted for a car to list toward the edge of the road or down off the crown of the road?

MR. VINCENT:—I suppose that question refers to driving on the crown of the road and then putting on the brakes, and to the tendency for the car to swerve off to the side. Of course, that would be true if the front axle were not designed properly or if the brakes were not equalized properly. I have had some experimental cars that did just that. The car was not partial as to which side of the road it took. It depended upon which brake was adjusted tighter. I feel that the king-pin axis must practically intersect the point of tire contact, and then the brakes must go on practically equal. They must be equalized and designed so that there cannot be any great difference in the efficiency of each brake.

QUESTION:—Do you anticipate any trouble from cables seizing in the cross-tube due to rust and corrosion or failing to equalize? Is lubrication provided for?

MR. VINCENT:—We use galvanized cable and the whole assembly is rust-proofed before painting. I do not anticipate any trouble. Of course, the movement is not great; so far as the rear brakes are concerned, it is not 1/16 in. in 6 months. The front cables operate a little every time we turn so that, probably, they will be kept free, and so will the pulleys. I do not say that the mechanism cannot get stiffened-up by corrosion and dirt, but it is pretty well protected.

QUESTION:—In reference to having the king-pin axis intersect the center of tire-ground contact, what is the angle of the king-pin and of the steering-knuckle?

MR. VINCENT:—Theoretically, the axis extended intersects the tire-ground contact. Its angle is 10 deg.

QUESTION:—What is the effect of having oil on one front-wheel brake?

MR. VINCENT:—About the same as having oil on one rear-wheel brake; to make it inefficient. If the brakes are put on to make a quick stop, some of the braking power is lacking. On account of the arrangement of the king-pin, we would not get any decided pull to one side of the road. We might do so under certain conditions, as when the tire rolling on one side of the road gets a slight pull, but nothing serious would occur to interfere with steering. The result would be very much reduced efficiency in the brakes. The only thing we can do as to that is to design to keep the brakes as dry as possible. I have not experienced the condition mentioned. Probably it will occur under certain bad conditions on the outside of the road, but it is pretty well guarded against.

QUESTION:—Of what material are the transmission gears and shafts made?

W. R. GRISWOLD:—We use an oil-treated chrome-nickel steel for the transmission gear.

QUESTION:—What type of gear-tooth is used, involute or stub, and what is the pressure angle?

MR. GRISWOLD:—All modern gear-teeth are of the involute form. That is the only type of gear-tooth that can be reproduced easily by methods that are available. So far as the design of the tooth is concerned, that is entirely special. The pressure angle is about 18 deg. 45 min. Compared with a full-depth Brown-and-Sharpe tooth, the tooth is shorter. However, the addendum and the dedendum of the teeth are not equal. They vary in such a way that the number of teeth in simultaneous contact, or the overlap in the engagement of one tooth to the next, the sliding factors and the tooth pressures or unit pressures between the faces of the teeth, are coordinated in a way that we desire to have them.

QUESTION:—What is the engine compression-pressure, gage?

MR. VINCENT:—The compression-pressure, gage, is approximately from 75 to 80 lb. per sq. in. with the engine warm and cranked over at 120 r.p.m. with the throttle wide-open. All readings on a pressure-gage depend upon how they are made. We have a fixed method of taking them. The speed we use is about the same as that at which the electric starter will crank the engine. We aim for 77 lb. per sq. in. gage pressure. The maximum torque is about 2730 lb-in.

QUESTION:—Does the single-eight offer any particular economy in fuel? What is the mileage per gallon of gasoline?

MR. VINCENT:—Gasoline economy is purely relative. The more excess power we put in the car the worse the fuel economy will be. I usually hesitate to give figures on fuel economy; they depend too much on how the car is operating. If I take a new properly adjusted car, at Detroit, on a 500-mile run, it will average anywhere from 12 to 14 car-miles per gal., but that is for straightaway driving and not for city driving. Under average operating conditions the year through one should get somewhere around 10 miles per gal. I do not say that we offer any particular economy in fuel-consumption over that of any car of the same power; but I do believe that, on account of the simplicity of the engine, it is easier to maintain it in reasonably good working order so that it will give somewhere near the economy it should give.

QUESTION:—Having the brakes arranged so that they will not lock is a good way to save tires. What conditions are chosen? Is there some specific coefficient of resistance with the road?

MR. VINCENT:—That matter is not clearly answered in the paper. It is a difficult statement to make clear but, under ordinary dry-pavement conditions, it is very difficult to lock the wheels if there is anything like the proper brake adjustment. It can be done. The rear wheels will lock first; it is very unusual to be able to lock the front wheels, but so long as the human element is involved and so long as the brakes are made relatively efficient, there will be a possibility of locking them. That is my reason for believing that brakes should not be so sensitive that they can be locked easily. However, I do not think that the average person would lock them except under very extreme conditions. I do not say that the wheels cannot be locked, but that it is very difficult to lock the front wheels.

QUESTION:—What is the ratio of the thrust to the radial load on the steering-worm bearings?

MR. GRISWOLD:—The reference is, I understand, to the bearings, top and bottom, of the worm. The radial loads are relatively very small. In fact, they might even be neglected entirely, because the thrust acts along the center-line of the worm-shaft. I do not recall what the thrust loads are.

QUESTION:—Has the reduction in friction in the steering connection produced any tendency to wheel-wabble?

MR. VINCENT:—That is a very nice problem to get around because it certainly is true that anything which can be steered easily from the steering-end standpoint will be fairly easy to work back through the other way. I think we all agree that for high speed, powerful cars, it is very dangerous to put in irreversible steering. It will simply result in breaking something. Irreversible steering will not stop the wheel-wabble or the so-called "shimmy."

The first edition of the present axle was of about the same shape as it is now, but it produced wheel-wabble of the ordinary variety that occurs at low speed. In checking that up, I found it easy to correct by reducing the fore and aft rake angle of the king-pin or the inclination back to the front. The first angle was something like 3 deg. I could eliminate the wabble by reducing that angle to 2 deg. However, later on, when we got to experimenting with various kinds of big tire, we ran into some other kinds of wheel-wabble at high speeds and found it necessary to reduce that angle still further. Now, it is an angle of 1 deg. with the car fully loaded, and of about $1\frac{1}{4}$ deg. with the car unloaded. We find it very important not to have too much angle. Since we settled that angle question, I have been unable to make the car shimmy at high speed, and we have had no trouble when driving at low speed except when I experimented with some of these new tires.

QUESTION:—How does the four-wheel-brake construction operate on the single-eight when balloon tires are used at high speeds?

MR. VINCENT:—So far as I know, the four-wheel brakes would operate very well. The balloon tire has many good features; one, in particular, is that it certainly grips the pavement well; so, I imagine one would stop a car very quickly if the brakes were put on hard enough. I have not tried to stop at very high speed, because I have not been able to get up very high speed without wheel-wabble with the balloon type of tire.

QUESTION: We see that the short V-type engine has been abandoned in favor of a long straight-line engine. This is just the opposite of the development that the aircraft engine has had in the last 10 years. The long straight-line engine has been abandoned and I believe that the short V-type engine is now leading. Can Mr. Vincent predict from his experience with the single-eight engine whether anything similar will be the case in the aircraft engine?

MR. VINCENT:—I think not, except that we might have a twin-eight engine for large powers. When we try to use aircraft ideas too far in our automobiles, or vice versa, or try to mix up car design and truck design, we get into considerable trouble. We learn much in each branch of the art but we have to be very sure to analyze the problems of the particular job before us. In the case of the aircraft engine, I am not in full agreement with the statement that we have abandoned the long engine for the short engine. We have abandoned long engines for long "double" engines, if one may put it that way, because we have gone up in power and we have to use two rows of cylinders just about as long as the single row was in the first place. I think that the eight-cylinder V-type engine will not continue to live in aircraft work. I think that the light high-powered, 12-cylinder engine will be the standard aircraft engine, at least for Army and for Navy work. Twin-eights, or 16-cylinder engines, have been built, and it is entirely possible that there will be a development along that line; but I believe that, for aircraft work, the 12-cylinder engine will be used in increasing numbers because it is the lightest engine in weight per horsepower that can be built.

QUESTION:—The use of cables for controls on airplanes has been almost discontinued, largely because of the exceptional strain on the cable. Why, therefore, do you turn to cable for your brakes rather than to the bell-crank as used in aircraft construction?

MR. VINCENT:—I can answer that best by saying that we do not have the same sort of conditions at all, although I cannot agree with the statement that the use of the cable for aircraft work has been discontinued. There is a movement in that direction, but the problem involved is entirely different from that in motor cars. In the airplane we want to get movement in both directions; therefore, we have to run cables clear around and that creates considerable friction in itself. We want to get the easiest possible control on the airplane, the best touch. That is very different from just pulling on the brake-shaft. I do not know of any way to equalize brakes simply as well as it can be done with cables. I do not say that that is the ideal way, but it is the best way I know.

CAUSES OF ACCIDENTAL DEATHS

IN the report of the committee on accident prevention of the National Safety Council, which was submitted at the recent Safety Congress at Buffalo, the chairman of the committee, Dr. Louis I. Dublin, statistician of the Metropolitan Life Insurance Co., had the following to say about the relative seriousness of the different hazards principally responsible for fatal accidents in this country in recent years.

The committee estimates that in 1922 14,000 deaths in the United States were due to automobile accidents alone. In 1911 the number was only 2061. In the intervening years automobile accidents accounted for 2.6 per cent of accidental deaths. In 1922 the automobile was the chief cause and accounted for 18 per cent of the total accident mortality budget. The accompanying table presents a comparison of the estimated fatalities in the United States during 1922 and for the three other calendar years of 1911, 1920 and 1921. —*Economic World.*

CAUSES AND ESTIMATED NUMBER OF ACCIDENTAL DEATHS

	1922	1921	1920	1911
Accidental burns	6,009	6,362	8,088	7,214
Accidental drowning	6,992	7,872	6,066	8,806
Accidental falls	12,782	12,293	12,557	14,052
Traumatism by machines	3,168	1,941	2,660	1,967
Railroad accidents	6,883	6,362	7,769	12,179
Automobile accidents	13,875	12,293	11,067	2,061
Street car accidents	1,748	1,725	2,128	2,998
All fatal accidents	75,272	73,542	75,983	79,255

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

OBSERVATIONS ON THE AUTOMOTIVE AND HIGHWAY FIELDS IN EUROPE

TO those readers of THE JOURNAL who are interested in the many new developments that have come crowding upon one another's heels during the past 12 months of the automotive industry's history, the following notes, made more or less at random in the course of a short trip through England, France and Germany this summer, may be of interest. These notes, covering aspects of the industry that seemed most interesting to an American observer, are given under subject headings for the convenience of the reader.

HIGHWAY CONSTRUCTION METHODS IN ENGLAND

Upon the subject of highway construction, the observations of Col. R. E. Crompton, equally well known as an authority in this field and as the inventor of the tanks, were of interest. His paper, read before the Institution of Mechanical Engineers in 1916, described the British construction methods with great thoroughness, and so far as he is aware there is nothing new to report since that date. His particular concern at the present time is for the support of the sides of macadam roads cross-tied together to prevent spreading.

MACADAM ROAD SURFACING

Colonel Crompton described his method of producing a satisfactory macadam surface when the roadbed is old and solid. This is somewhat as follows: First scarify the old surface, taking off the material and cleaning it; then add about an equal amount of new material about the 2-in. size and roll into a compact surface between the side buttresses. Put over these a layer of new stone about ¾ to 1 in. in size, of a type of material that breaks into almond-shaped pieces; this may be broken from some of the old material. This is brushed to get it to stand on end in the interstices of the larger stones and then rolled hard. Next a layer of asphalt or pitch is applied to consolidate this surface, after which a ¾-in. layer of top dressing broken from the old road is added. Finally this is put down with pitch mixed with the correct amount of fine material, 200 mesh or so, which is, as well as not, recovered from the old road material.

For British service, which can rely upon good road foundations and where there is still much heavy steel tire traffic, Colonel Crompton thinks roads of this type are preferable to cement. The latter has not been found entirely satisfactory, while the macadam roads made as above have shown remarkable life. He also has a plan for the continuous upkeep of such roads, which he estimates to be very inexpensive, perhaps sixpence per square yard, and to be applied only once in 2 or 3 years.

HIGHWAY UPKEEP AT TRIFLING COST

This calls for a train of vehicles drawn by a tractor and covering about 6 ft. wide at a speed of 1 m.p.h. First the road is swept clean, then comes a machine to spread the surfacing stone of ¼ to ½ in. in size. After this is spread evenly, a tar-wagon throwing a high-velocity spray of pitch with superheated steam into the stone follows and then a roller or two that compacts the whole. If this process is applied at reasonable intervals, he thinks the road should be permanent. This seems likely, provided the foundations are good.

In general it seems that much of the difference in quality of road work in England and in the United States is due to a great difference in the care, skill and intelligence of the workmen and foremen who do the work on the road. So great is the difference between British and American conditions in these respects that the difference in road due to this cause alone may easily average 3 to 1.

RUBBER ROADS FOR QUIET ZONES

Another noteworthy item was a sample of the rubber road that is being laid to surround the Cenotaph in Whitehall, the object being the reduction of noise in this particular locality. This consists of a concrete brick with a layer of about ⅜-in. of rubber vulcanized all over it. The rubber is very hard, much more so than tire rubber. The surface of the concrete has pits into which the rubber is vulcanized to add to the adhesion. This type of road is found very effective in the neighborhood of hospitals. Other roads of the same material now in use show almost no measurable surface wear, and long life is predicted for this comparatively thin layer of rubber.

LONDON GENERAL OMNIBUS SERVICE PLANT

At the Chiswick works of the London General Omnibus Co. is a most interesting example of the application of real organized production methods to the systematic overhaul of buses. It is a police requirement in London that all public service vehicles shall be taken down and overhauled once every 12 months. Based on this requirement the system described below has been worked out.

DISMANTLING AND OVERHAULING

Every morning, about 25 buses come into the service plant. First the body is removed to a special elevator, after which the chassis is driven around to the take-down line, while the body is taken to the body works. In the latter section the entire body is gone over for repairs, replacements or necessary modifications, in case standard fitting has been changed. After being repaired the body is entirely repainted from the surface up, in three coats. This operation requires not more than 48 hr. In the take-down line the chassis is completely dismantled, even every brace and bracket being removed from the frame. The only bolted parts that remain are the bolted-in cross members.

The engine is taken off at one distributing center, the transmission at another and the rear axle at a third. Each of these units is broken down to the very last piece and the dismantled parts are then passed through a cleaner in which they are subjected to high-pressure sprays of hot caustic solution that remove all grease and dirt and leave all parts perfectly clean, except the pistons, which have to be freed from carbon deposit. These cleaned parts are then distributed on several lines of rollers, six lines being devoted to the engine, and at the end of each line the parts of a kind are fed at random, each into its own repair or receiving line. Here each part is inspected, measured,

INTERCHANGEABLE STANDARD PARTS

A most interesting feature of this system is, that each [illegible] from two to nine or more standard [illegible] the company's process involves refinishing all worn parts to the next size. There are two standards for cylinders and each pair of cylinders that is worn beyond [illegible] number of thousandths is reground and burnished to the second size, which is 1 mm (0.03937 in.) larger in diameter. Incidentally, all work is in metric sizes except the fastenings, which are in thousandths of an inch. For crankshafts there are five different standards, each 0.5 mm (.01968 in.) smaller than the last, and within each standard the parts are absolutely interchangeable. Tolerances are ± .0001 in. The finished recovered parts go [illegible] to the assembling line, and the engines, transmissions, rear axles and finally the entire vehicles are assembled in the usual way. The chassis goes through to the [illegible] platform moving at the rate of 14 in. per min. Engines are all turned on electric stands, as is the best practice for new engines.

The entire process is completed so rapidly that it is possible to put a frame that goes in for overhaul in the morning in trim and the same night as a complete bus and go on the road for test the next day. Of course, it could not [illegible] the same body and some of the parts do not get [illegible] in that space of time, but most of them do.

REFINISHING OPERATIONS

In the refinishing operations, such as regrinding crankshafts a stock of each standard is allowed to pile up at the [illegible] so that the operatives can work all day on one size standard to avoid loss of time in setting the machines. The same is true of some other parts. The setting of the shaft and the connecting-rod bearings is interesting. The [illegible] is brought into the bearings, which are put into the [illegible] hot from the tinning bath. Oil-grooves, etc., are [illegible] and the amount of extra metal is only very little. Then the [illegible] as on the bench and when mounted in the machine are set-up tight and reamed on a special [illegible] that is also a burnisher. The tool has a reverse [illegible] the cutting and burnishing edges and the latter are [illegible] like dull cutting edges. This brings the liners to a beautiful finish. Absolutely no sandpaper is done on them and the fits are perfect. A special set of guides on the reamer insures alignment.

Cylinders are finished by hard steel burnishing rollers. It is claimed that this process adds 2 months or more to their life, say 5000 miles.

TESTING THE OVERHAULED CHASSIS

After assembly the chassis rolls onto a pair of drums that start the engine through the rear wheels and a driver takes it away. This driver, who is a special inspector and adjuster, is given 5½ hr. to see that this chassis is in perfect shape by driving it around a test track on the grounds. He makes minor adjustments himself, but reports back defects other than these to the repairs department, which handles them. Sometimes these inspectors report a whole sheet of minor troubles. Another factor that makes for efficiency is the fact that the system itself tends to pit one group against another so that nothing is shirked. Every engine is overhauled once between the general annual overhauls, that it, once every 6 months, and this is done with the same thoroughness as described above. On the average, it takes only 29 man-hours to do this job.

A REMARKABLY CENTRALIZED SYSTEM

The Company has some 30 garages in the city of London and operates about 4000 buses. These garages make minor adjustments such as those on brakes, but hardly any repairs. In fact, hardly any are necessary. The main units are all easily removable and in case anything goes wrong the garage replaces the whole unit, be it engine or steering-gear, and sends back the damaged unit to the main repair station.

MINIMUM MAN-POWER USED

One feature of the plant is the small number of unproductive employes. The system of passing work along is so well organized that no man-power is used for it. The office staff is correspondingly minimized. Altogether about 2500 men are employed at the plant. Assuming that the Company operates 4000 buses, this leaves a little over one-half a man's time for each bus. Since each bus is a 56-passenger vehicle with an infinite life, the upkeep cost would appear to be very reasonable. The expression "infinite life" is used to convey the idea that there is no obsolescence, except for scrapped individual parts. Bus fares in London vary in proportion to the distance traveled, but the average is probably less than 5 cents.

PRODUCTION

NOTHING remains stationary. Advance or decay is the law and fact in nature and commerce. Production methods and machine tools are constantly improving, and these forces increase the value of their products. While the price remains unaltered, less value for money is being given. The latter, rapidly finds its level, and only those first in the field reap the initial advantage of the new methods. The others, finding that they must come into line on a price basis, under the compulsion of necessity adopt improvements in production without experiencing any of the benefits that accrued to the first comers for a very brief period.—*Automobile Engineer.*

THE AUTOMOTIVE INDUSTRY

THE magnitude of the automotive industry is well illustrated by recent publications indicating an annual production of approximately $3,000,000,000, while petroleum, the second greatest industry, is credited with only two-thirds of that figure, and the cotton industry is shown with an annual output of just about 40 per cent of the leader. In the insurance world, it is second only to the principal line, that is, fire insurance.—W. B. Burpee.

Research an Important Factor in Highway Improvement

THE third annual meeting of the Advisory Board on Highway Research of the National Research Council was held at the headquarters of the Council in the City of Washington, on Nov. 8 and 9, 1923. The fact that advances in engineering knowledge evolve from investigation in new fields of research was indicated most clearly by the report of Dr. W. K. Hatt, director of the Board. In contrasting the present status of highway problems with that which obtained only 3 years ago, when the Advisory Board was inaugurated, he left no doubt as to the accomplishment of great progress during the period.

At the earlier date it was stated that no engineer could then build a concrete, bituminous or brick road with any certainty that it would carry traffic of motor trucks under specified conditions without breaking rather than gradually wearing under the loads imposed upon it. On the other hand, the experienced highway engineer of today, by using available information, can choose materials and design the section with reasonable assurance that it will withstand the specified conditions of service.

This raises the question of the adequate analysis and prompt distribution of the results of research, two extremely important factors in their most effective application. Activities of the Advisory Board in disseminating such material in published form and otherwise and in helping to coordinate the work of various research agencies were mentioned. In this connection it was suggested that the Board might well inaugurate an information service capable of maintaining better contact between highway engineers and the sources of information.

The director commented upon the work of the research committees and emphasized the desirability of making available for the problems of the Board more of the time and energy of the workers whose activities are now necessarily directed only in part to Board matters.

Doctor Hatt reviewed briefly the activities during the year of the various research committees and discussed the cooperative relations existing between the Advisory Board and other organizations, which number about nine, including the Society of Automotive Engineers.

It was stated in a report of the sub-committee on tractive resistance, which functioned under the leadership of Major Mark L. Ireland, that a large amount of data has been accumulated, some of which has already been distributed in preliminary reports. In concluding his report, Dr. Hatt discussed ways and means. He also enumerated the publications issued by the Board and listed the public addresses of the director.

Economic Theory of Highway Improvement

Characterizing the committee on Economic Theory of highway improvement as an informal association of men engaged in a certain line of research, Chairman T. R. Agg gave a brief account of the field that the committee seeks to cover and the progress already made. Projects on which results have been published, or are in process of publication, are truck performance on grades, rolling resistance and related characteristics of roadway surfaces, cost of motor-vehicle operation, economics of highway grades and quartermaster tractive resistance of roads research. Projects in progress include wind resistance of motor vehicles, relation of road type to tire wear and further investigation on the first three topics above.

Some of Those Who Attended the Meeting of the Advisory Board on Highway Research

Research on Tires

The work described in this report was carried on at the Bureau of Standards with a view to establishing a better basis for tire purchases. The chief problems in connection with tires were mentioned, a laboratory endurance testing machine was described and a series of tests outlined which would be of value to the Government in making purchases and to manufacturers in determining a standard test for the tire industry in general.

Deceleration Tests of Automobiles

Recent developments in the measurement of braking characteristics of automobiles were discussed by W. S. James of the Bureau of Standards. The interesting features of a new decelerometer, described in detail in this issue of THE JOURNAL on p. 499 were explained. Tests with this instrument have shown that high tire-pressure is an important factor in causing irregular

stopping. A surprising feature of the tests to determine coefficients of friction on surfaces ranging from plate glass to mud was that in all cases except on muddy surfaces the coefficients are greater for sliding than for slide friction, even that the highest coefficient was found on plate glass. Mr. James stated that his instrument and method offer a convenient means for an inspector to check the condition of brakes on any car. Furthermore, this method might serve as a basis for legislation regarding brake capacity.

Structural Design

A. T. Goldbeck, chairman of the committee on structural design of highways, reported research work on the subgrade, which comprised capillary moisture tests; the devising of apparatus for testing soils under many subgrade conditions, including a new slaking test and a new method for making soil cylinders; the determination of different physical properties of soils at various points and under various conditions; information upon colloids in clays; data on 13 clays from 10 different localities in Ohio; besides the Bureau of Public Roads tests having as their aim the standardization of physical tests for subgrade material, the determination of efficiency of admixtures and tests to determine the laws of moisture in the subgrade. Other subjects mentioned in the report were principles and methods for sand-clay, top-soil and semi-gravel road construction; forces on pavements resulting from traffic; conclusions drawn from the Pittsburgh and from the Bates road tests; and a theoretical analysis of stresses in road slabs. The report included 26 topics suggested for further research.

Mechanics of Stiff Road-Slabs

The behavior of road slabs when supported on an elastic subgrade and loaded in different ways was discussed by Dr. H. M. Westergaard, of the University of Illinois, who has made a mathematical study of the subject. He showed equations and curves illustrating the distribution of stress in various types of slab under distributed and concentrated loads applied at the edges and also at the center. It was evident from Doctor Westergaard's mathematical treatment that it offered possibilities of solving numerous problems of concrete road design.

Character and Use of Road Materials

H. S. Mattimore, chairman of the committee on the character and use of road materials, listed in his report the 12 problems undertaken and stated briefly the progress made in each case. Among the definite conclusions reached as a result of this investigation were the following:

> The strength of Portland cement concrete varies with the amount of actual solid material present in a given volume and with the relative parts of this volume that are cement and aggregate. . . Other conditions being the same, the grading of the aggregate has a decided effect upon the quantity of water that can be used to form a workable mixture. . . Concrete when tested in the wet condition shows a decrease in strength from that which is tested dry.

Objectives of Highway Research

Thomas H. MacDonald, director of the Bureau of Public Roads, delivered a brief address on the subject of Objectives of Highway Research. He strongly emphasized the need for study on the basic problems of highway design and pointed to numerous instances in which the results of apparently insignificant researches have contributed to success in various engineering lines. He called attention to the immense field still left unexplored. In connection with the problems of highway transportation, he made a plea for a better recognition on the part of the public authorities of the importance of research in this general field.

Land Grant Colleges Cooperate

Anson Marston, dean of Iowa State College, presented two reports on behalf of the Association of Land Grant Colleges. He pointed to the great advantages offered by these institutions for research work on highways and mentioned the fact that in 1923 they have expended about $550,000 in engineering research. Furthermore, he stated that research on highways has been undertaken in the colleges of 24 of the States.

Highway Finance

After enumerating some of the economic and social advantages resulting from highway improvements and mentioning the chief faults in present methods of highway financing, Mr. J. G. McKay, chairman of the committee on highway finance, named six chief sources of funds for this work, recommended the budget system and gave as the two distinct problems involved in highway finance: (*a*) an equitable distribution of the cost among the several sources of revenue and (*b*) the question of the use of credit. He stated the conclusions based on the analysis of the sources and expenditures of highway funds in four representative counties and named three courses that may be followed in reducing real property taxation for highway improvements, advancing the opinion that where increased revenue is needed, it should come from the highway user whose demand for highway service is largely responsible for highway improvements.

Highway Research in North Carolina

Charles M. Upham, State highway engineer of North Carolina, gave a very interesting illustrated talk, explaining the methods used in the State of North Carolina to overcome the serious difficulties encountered in the demand for reasonably satisfactory highways in a State where the taxable property and the funds available for construction are extremely limited. In contrast with early primitive conditions in his State, he showed a number of apparently well-constructed and satisfactory modern highways, the methods of construction of which were interesting for their unusual character. One type of road consisted of nothing other than the native sand with a comparatively small amount of bituminous binder, the road being built-up by careful processes that result in a very satisfactory highway. It was demonstrated that good results can be obtained by the application of ingenuity and originality where conditions render the usual methods of construction impossible.

Highway Traffic Analysis

The importance to highway engineers of the traffic census and transport survey were brought out in the report of G. E. Hamlin, chairman of committee 4 on highway traffic analysis. In emphasizing the difference between the census and the survey, Mr. Hamlin stated that the former gives information pertaining to the traffic using the highway at the time the census is

(*Concluded on p. 510*)

Photoelastic Method Applied to Rigid-Airship Research

By THOMAS H. FROST[1]

Illustrated with PHOTOGRAPHS

THE photoelastic method, concerning which extracts have been published[2] previously, is an optical method for the determination of stresses in all types of structures. A model of the structure, made of some transparent isotropic material, is subjected to stress under polarized light. The resulting image when projected on a screen is highly colored because of the temporary birefracting power of the material when stressed. Analysis of these colors determines in most problems the existing stresses within an error of from 2 to 5 per cent. This photoelastic method, though applicable to all structural problems, realizes its greatest importance when used for determinations of stress in mathematically indeterminate structures of which rigid airships are an extreme example.

In the design of rigid airships, a problem utterly different in many respects from all other types of construction, it becomes necessary for the engineer to depart radically from the more or less conventional methods. Naturally, the primary requirement that always must be kept in mind during calculation is the saving in weight wherever this is possible.

To effect this saving a peculiar combination of girders and steel wires has been adopted. The lightest structural metal obtainable, duralumin, is used throughout, and the factor of safety has been cut down to a figure that would be instantly condemned in any other field of engineering. Considering these facts, it becomes apparent at once that extreme accuracy of design and calculation and perfect construction are vital for the safety of the ship.

The design of the new Navy dirigible, the ZR-1, which was constructed at Philadelphia, and Lakehurst, N. J., has been based on the German Zeppelin, L-49, captured by the French in 1917. While the ship was under construction, the Bureau of Aeronautics of the Navy Department decided to carry out photoelastic tests at the Massachusetts Institute of Technology, to determine the stress distribution with the ship in flight. This work has been carried out by Dr. Paul Heymans, assistant professor of theoretical physics, who established the photoelastic laboratory, and myself, in cooperation with the Bureau of Aeronautics through C. P. Burgess, aeronautical expert for the Navy Department.

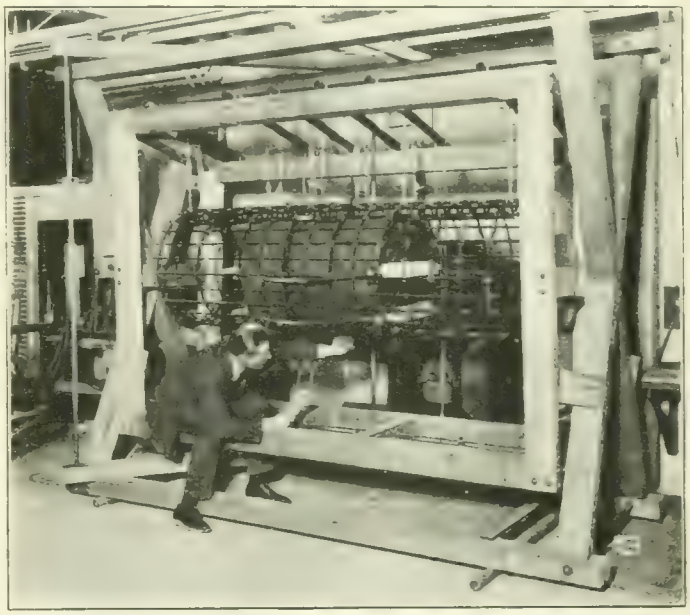


FIG. 2 THE MODEL IN PLACE IN THE LOADING FRAME

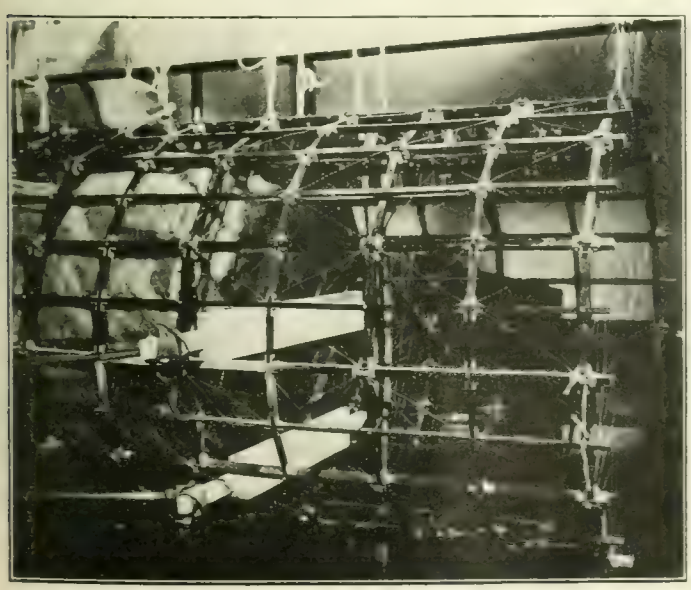


FIG. 1—SIDE VIEW OF THE MODEL OF THE ZR-1 ON WHICH THE TESTS WERE MADE

THE MODEL

The model shown in Fig. 1 embraces the seven central frame-spaces of the ZR-1 and is constructed on a scale of approximately 1 to 33 of the actual dimensions of the ship. The individual girders are not triangular lattice-work as in the actual ship, but are plain rectangular sections that have been calculated under imposed conditions of elastic similarity, to assure the same distribution of stress when the model is loaded that would arise in the actual ship under flight conditions. The girders of the model are made of pyralin, a transparent material of camphorated nitro-cellulose base, to allow the free passage of a beam of polarized light.

On account of the change of shape of the girders for the model, the joint system used in the actual ship could not be used in the model. A system of bolts and angle-plates was devised to assure rigid joining.

The wires of the longitudinal-shear wiring system must be placed under certain known initial tension during the construction of the ship. In the model, since

[1] Resident associate in photoelasticity, physics department, Massachusetts Institute of Technology, Cambridge, Mass.

[2] See THE JOURNAL, October, 1920, p. 393.

various tests of different nature were to be carried out, it became necessary not only to place the shear wires under known initial tension, but also to provide for changing this tension at will. In order that this could be done the terminals of the wires were passed through holes in the ends of small tapered pins that fitted into tapered holes in the small steel hardened plates covering the joints. The pins were turned with a key, with the result that the wires could be stressed in much the same manner as a violin is tuned. The determination of the wire loads was accomplished by a small Larson tensiometer that was specially made for these experiments.

The model was placed in the loading frame, shown in Fig. 2, the inner section of which, containing the model, could be swung through any desired angle. This, of course, made it possible to pass the beam of light, which remained in a horizontal plane, through any desired longitudinal girder.

The loading of the model has, in most cases, been simulated by dead weights suitably disposed about the framework. To represent the gas-pressure forces from which a considerable fraction of the existing secondary stresses arise in the actual ship, the model was equipped with water-tight bags in the three central frame-spaces, which were filled with water while the model was in an inverted position, keel upward. The model has been tested during the last 4 months for various stress conditions corresponding to positions of the ship in flight.

This investigation, which may without exaggeration be said to be the largest photoelastic stress determination yet attempted and the only one of its kind, is the first of a large series to be carried out at the Massachussets Institute of Technology. Since the establishment of the laboratory by Dr. Heymans, the volume of the work handled has been steadily increasing. At the present time steps are being taken to duplicate the present apparatus so that the laboratory can cope with the large number of problems presented by industrial organizations.

THE PRICE OF WHEAT

THE price of wheat from day to day in central markets is a consensus of world opinion as to its value, with all factors in the situation taken into account. The local markets where the farmers sell are more restricted, but the daily papers carry the quotations of the central markets to every village and farm, and the local markets are not likely to be far out of line. Moreover, the task of moving the crop from the farms to the central markets is quite distinct and different from that of attempting to control the latter. The farmers' cooperative elevators can operate with little risk because they have the hedging facilities of the central markets; but when the farmer sets out to operate independently of the markets, or to control the markets, he takes his place with the other speculators, with possibly one economic factor in his favor, to wit, ability to carry his own wheat in his own granary at lower cost than it can be carried in the cities.

Of course, there is no reason why the farmer should not make the most of this single advantage which he has over the speculators, whenever prices fall below the normal level indicated by production costs; he is on safe ground there, and the stabilizing influence of farm reserves would be beneficial to the markets. It is quite impossible, however, that any association of farmers, no matter how many are included, can ever adjust prices to suit supply and demand as readily and effectively as the present system of free trading does it. No single group of men can fix the market price of a world commodity. That idea is a fantasy.

If too much wheat is being grown, production should be restricted, but this is best accomplished by having each individual producer free to adapt his policies to his own conditions, rather than by having every producer reduce his acreage in accordance with instructions from headquarters. In the first place, the officials at headquarters are fallible and may blunder. In the second place, all farmers are not growing wheat under the same conditions or at the same cost. All the Government inquiries into the cost of growing wheat have shown a wide range of variations. All farms are not equally suitable for growing wheat; some can be shifted to various crops more advantageously than others. Some farmers have help enough within their families to farm all the land they have, while others are obliged to hire help, and there are other conditions which may have bearing upon the advisability of curtailment in individual cases.

The chief cause of agricultural distress today is not low prices for agricultural products, most of which are above the pre-war level, but the arbitrary and short-sighted action of labor organizations in maintaining the cost of the goods and services which the farmer must buy far above the pre-war level, and in unfair relations to the prices of his products. The farmers may hold conferences until doomsday without getting any relief unless that disparity is reduced. The entire issue at last is over the terms upon which the exchange of services shall be made. The advantages of group-bargaining to employes would be almost wholly lost if the compensation of all workers, including farmers, was advanced at once. There are practically no gains except what they are clever enough to get at the expense of each other.—National City Bank.

Decelerometer for Testing Automobile Brakes[1]

By William S. James[2]

Illustrated with Photographs and Chart

THE application of the brakes of a moving car results in a reduction of speed. The reduction in speed is obviously the result of a force opposite to the direction of motion. The *rate* at which the car slows down is directly proportional to the retarding force. If the car is moving at a speed of 20 m.p.h. when the brakes are applied, and the rate of slowing down is 10 m.p.h. in every second the car will come to a stop in 2 sec.; if it is slowing down at the rate of 5 m.p.h. per sec., it will stop in 4 sec. The retarding force in the first instance will have been twice that in the second. If the rate of slowing down remains constant the distance the car will travel before coming to rest will be the product of the time required to stop and the *average* speed of the car during this time. The average speed during the stop in the two cases mentioned will be 10 m.p.h., an initial speed of 20 m.p.h., a final speed of 0 m.p.h. and a linear change of speed with the time. As 10 m.p.h. is approximately 15 ft. per sec. the car will stop in 30 ft. in the first case and in 60 ft. in the second. It will be seen at once that the rate of slowing down is directly proportional and the distance required for a stop from a given speed is inversely proportional to the magnitude of the retarding force.

It is also known that the retarding force required to slow down a car weighing 4000 lb. at a given rate is twice that required to slow down at the same rate a car weighing 2000 lb. It is, therefore, obvious that to stop a 4000-lb. car in 30 ft. from 20 m.p.h. will require twice the force necessary to stop a 2000-lb. car in the same distance from the same initial speed. The retarding force *per pound or per* 1000 *lb. of car weight* is, however, the same with both the heavy and the light car, and results in identical stopping distances and rates of speed reduction. The above relations follow directly from Newton's second law of motion on the principle of the conservation of energy.

From the foregoing it will be seen that the effectiveness of automobile brakes can be measured directly by the braking force per unit of car weight, per pound, per 1000 lb. or per ton of car weight. The brake decelerometer designed at the Bureau of Standards is constructed in such a manner as to measure the braking force per unit of car weight. It consists essentially of a small bob-weight mounted at the upper end of a stiff flat spring. The spring is mounted vertically in the base of the instrument which is placed on the floor of the car so that the spring will deflect in the line of motion of the car. When a braking force is applied to the car a portion of this force is transmitted by the spring from the base of the instrument to the bob above it. This force is the same fraction of the total braking force as the mass of the suspended bob is of the total mass of the car. The force on the bob per unit of its weight is the same as the force on the car per unit of its weight. The spring is deflected an amount proportional to the force transmitted through it. The deflection of the spring is magnified by a lever system and calibrated by applying known forces per unit of weight of the bob and the instrument graduated in the desired units, pounds of force per 1000 lb. of car weight, rate of stopping in feet per

[1] Published by permission of the Director of the Bureau of Standards.

[2] M.S.A.E.—Physicist, Bureau of Standards, City of Washington

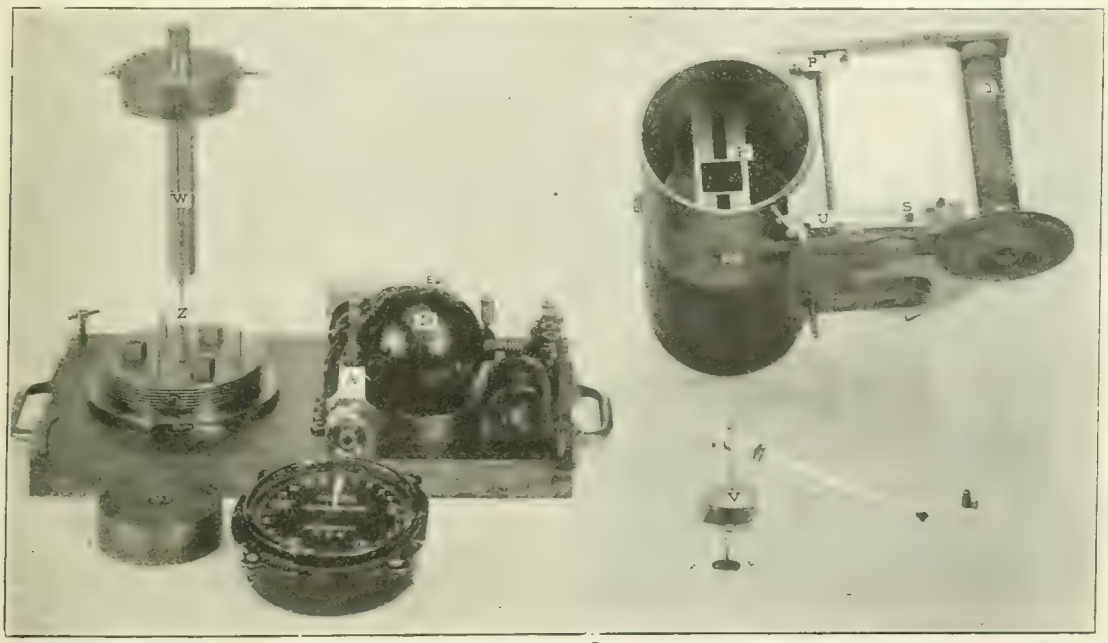
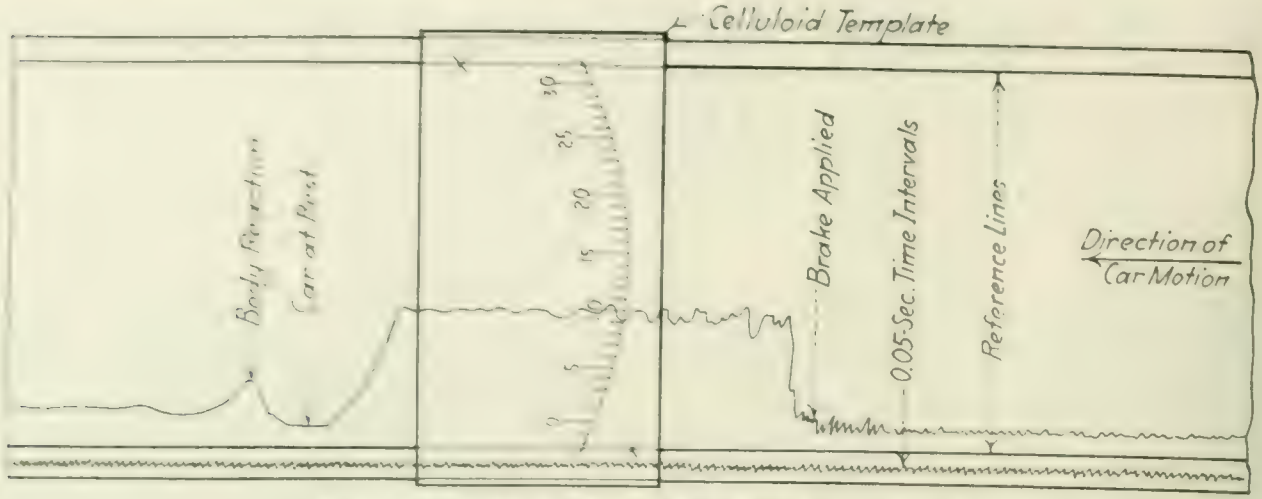


Fig 1.—The Bureau of Standards Decelerometer Disassembled

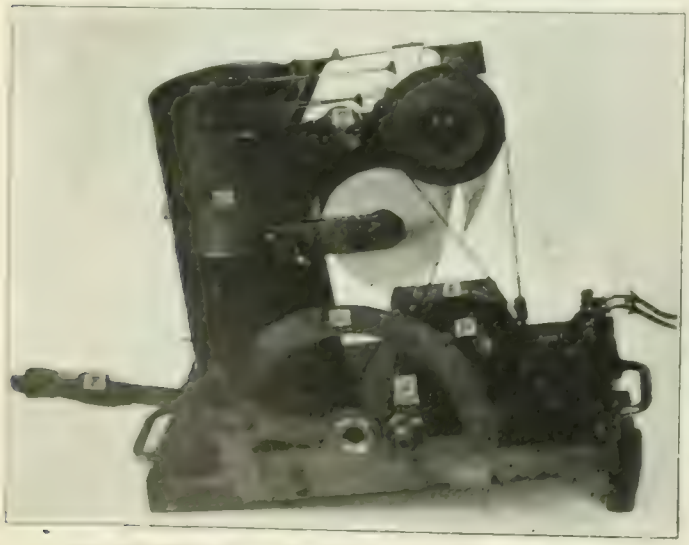


[illegible] Portion of Record Showing Action of the Decelometer

[illegible] per second or miles per hour per second or the distance to stop from an arbitrary speed.

Fig. 1 is a partially disassembled view of the instrument fitted with a recording attachment. The bob-weight *B* is supported above the stiff spring *Z*, which is rigidly mounted in the base-plate. When placed on the floor of a car the long axis of the base-plate is parallel to the line of motion of the car. The deflection of the spring *Z* is magnified by the stiff rod supporting the bob and the recording pen linkage *V*. The latter is supported by a cylindrical housing *G* that is screwed on the base-plate, and engages a short pin mounted on the end of the arm supporting the bob. The motion of the bob is damped by vanes *W* inserted in it and moving in oil-filled dashpots *P*.

The portion of the instrument just described is all that would be required for an indicating instrument. The recording mechanism was added for the purpose of a detailed study of brakes. By this means the deflections of the spring, as magnified by the multiplying system, are recorded on an unruled sheet of paper unwinding from a roll and drawn over a flat recording table by a 6-volt motor *D* that drives the roller *Q* through a worm and wormwheel and a belt. The paper feeds between the roller *Q* and an idler roller pressed against it by springs. To obtain a time scale on the records the pen *U* was mounted at one side of the recording tool and made to swing through a short arc, about 1/16 in., by a small cam and follower shown at *A* in the illustration mounted on the shaft of another 6-volt motor *E*. The motion of the cam-follower is transmitted to the pen *U* by a fine steel wire passing over the pulley *C*. The number of oscillations of the timing pen per second is obtained by a tachemeter driven from the shaft of the motor *E*.



[illegible] Interior View of Decelometer

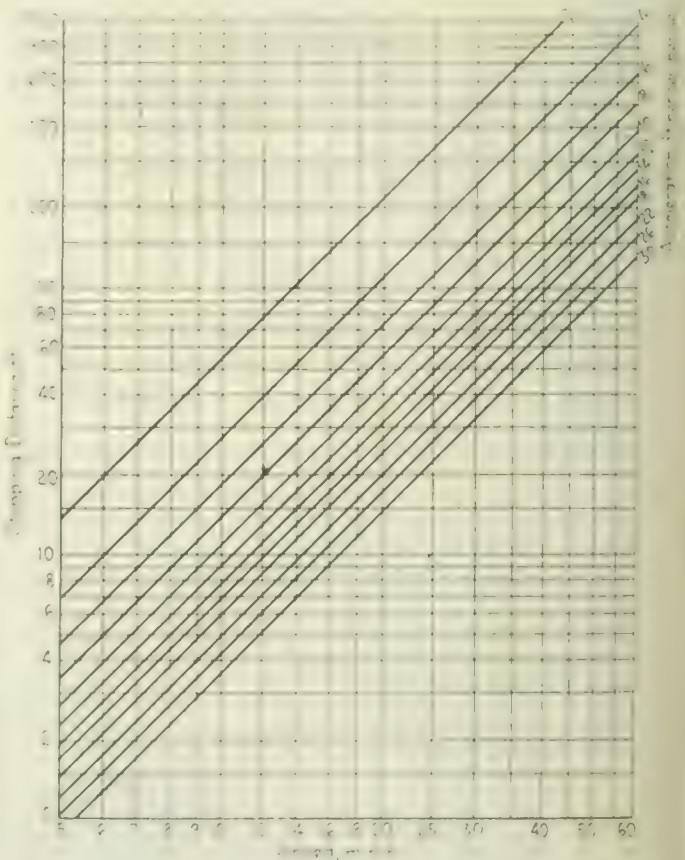


Fig. 1—Chart Showing the Relation between the Stopping Distance, the Initial Car Speed and the Rate of Deceleration

The method used to read the records is illustrated in Fig. 2. A transparent template is made by marking upon a piece of celluloid the arc through which the recording pen swings and the position of the two fixed

pens R and S shown in Fig. 1. These pens draw the reference lines as shown in Fig. 2 and the template is oriented on the record so as to bring their respective locations, as marked on the template by small crosses, over the lines drawn by the fixed pens. The intersection of the arc of the recording pen with the record gives the reading of the instrument in terms of the values marked upon the template. The graduations shown on the template in Fig. 2 are in feet per second per second. The time record is the wavy line near the edge of the paper and in this instance a swing of the timing pen occurred every 0.05 sec.

The method of calibration of the instrument is illustrated in Fig 3. A vernier protractor L fitted with a sensitive level bubble K is mounted on the base of the instrument. The instrument is first leveled and the protractor arm swung to a horizontal position as indicated by the level. The protractor is then read and the paper run for a few seconds to obtain the position of the recording pen with reference to the fixed pens. The instrument is then tilted through an angle, the protractor arm again leveled and the paper run for a few seconds. The protractor readings give the angle through which the instrument has been tilted and the records on the paper the corresponding position of the recording pen. The sine of the angle of tilt is the force applied to the weight in pounds per pound or if multiplied by 1000 the pounds per 1000 lb. of car weight. If the calibration is desired in feet per second per second, the value for any angle of tilt is obtained by multiplying the sine of the angle of tilt by the acceleration of gravity.

To obtain a record it is only necessary to press a button switch, thereby starting the paper-drive and timing-pen motors.

The relations between the distance required to stop s in feet, the initial car-speed v in miles per hour and (a) the rate of slowing down in feet per second per second a, (b) the rate of slowing down in miles per hour per second A, (c) the retarding force in pounds per pound F_1, (d) the retarding force in pounds per 1000 lb. of car weight F_2 and (e) the retarding force in pounds per ton of car weight F_3 are given in the following equations:

$$s = 1.08\, v^2/a \quad (1)$$
$$s = 0.735\, v^2/A \quad (2)$$
$$s = 0.0336\, v^2/F_1 \quad (3)$$
$$s = 33.6\, v^2/F_2 \quad (4)$$
$$s = 67.2\, v^2/F_3 \quad (5)$$

A plot of equation (1) is given in Fig. 4. Similar plots can be made to show graphically the other four relations.

If either rate of retardation or the retarding force per unit of car weight is known the distance within which a stop could be made if the initial speed were 20 m.p.h. can be found from the following relations which were obtained by substituting 20 m.p.h. for v in equations (1) to (5)

$$s = 432/a \quad (6)$$
$$s = 294/A \quad (7)$$
$$s = 13.44/F_1 \quad (8)$$
$$s = 13,440/F_2 \quad (9)$$
$$s = 26,880/F_3 \quad (10)$$

Judging from 250 records obtained with the recording decelerometer described, with about 35 different cars representing 22 different makes, of which the record shown in Fig. 2 is typical, it is believed that the rate of retardation or the retarding force per unit of car weight is sufficiently independent of the car speed to make the use of an indicating decelerometer practicable for the inspection of the condition of automobile brakes by the traffic authorities of large cities. A simple, rugged and portable decelerometer graduated to read in "feet to stop from 20 m.p.h." is now being built at the Bureau of Standards to illustrate further the practicability of this method for inspecting the condition of automobile brakes.

THE DIESEL ENGINE IN THE YACHTING FIELD

(*Concluded from p.* 452)

direction. Each problem is absolutely by itself and a general statement cannot be made.

CHAIRMAN L. C. HILL:—An interesting letter was received recently at the office of the Society complaining about a practice that the writer said had been followed in the motorboat trade for a number of years and is being followed today. He referred to the publication of inaccurate horsepower curves in motorboat magazines. Unfortunately, these curves are relied upon to design the lines of a ship and to select its propeller and its powerplant unit. It is often impossible in practice to come within 10 per cent of the horsepower curve anywhere throughout its length and in some cases it is necessary to rebuild the engine framing and re-design hulls that are three-quarters complete. Is not the publication of those curves bad practice?

MR. COLLEY:—I agree that the gentleman's complaint is justified, except that I think most naval architects have made it a point for the last 5 or 6 years to take from 10 to 15 per cent off the engine builder's curve and then suit the wheel to that condition to give a factor of safety for contingencies. As a matter of fact, our company makes it a practice to give figures about 10 to 15 per cent low. In most shops no two boats are alike and allowance must be made for weather conditions, skin-surface conditions and the various other things that affect the operation of a boat when it is placed in service.

L. G. NILSON:—At one meeting of the Society a number of years ago I suggested that we stop using the term "horsepower" and designate engines by their bore and stroke.

CHAIRMAN HILL:—I notice that the motorboat industry still continues to say that an engine is rated at a certain S. A. E. horsepower. There is no such thing as S. A. E. horsepower. The Society has no formula for horsepower and never has had one. The formula used was carried over from the old Association of Licensed Automobile Manufacturers' and at the time that organization went out of existence it was changed to the N. A. C. C. formula, taking its name from the National Automobile Chamber of Commerce.

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

AMERICAN STANDARDS NEEDED

Society Is Now Sponsor for Seven National Sectional Committees

With over 2,000 technical societies and trade organizations in the country, of which it is known that at least 300 are [illegible] standardization, it will be appreciated that standardization activities must be coordinated if a needless overlapping of standards shall not occur. This is of commercial as well as of technical importance, as conditions might confront a producer of a material in which a certain grade of his product would be acceptable in one industry and not in another, even though the real requirements of both should be identical.

To remedy this condition, *standards must be standardized*. To accomplish this a correlating agency is necessary, a clearing house for standards. This clearing house has been realized in the American Engineering Standards Committee, an organization composed of representatives of 9 leading national societies, 7 Governmental Departments and 19 trade organizations.

In carrying out its clearing-house functions, the American Engineering Standards Committee is restricted to insuring that all organizations interested, whether members of that body or not, are represented on the proper sectional committee. The sectional committees are generally organized by members of the American Engineering Standards Committee designated as sponsors. The sectional committee reports must be approved by the sponsors before they can be approved by the American Engineering Standards Committee as American Standards.

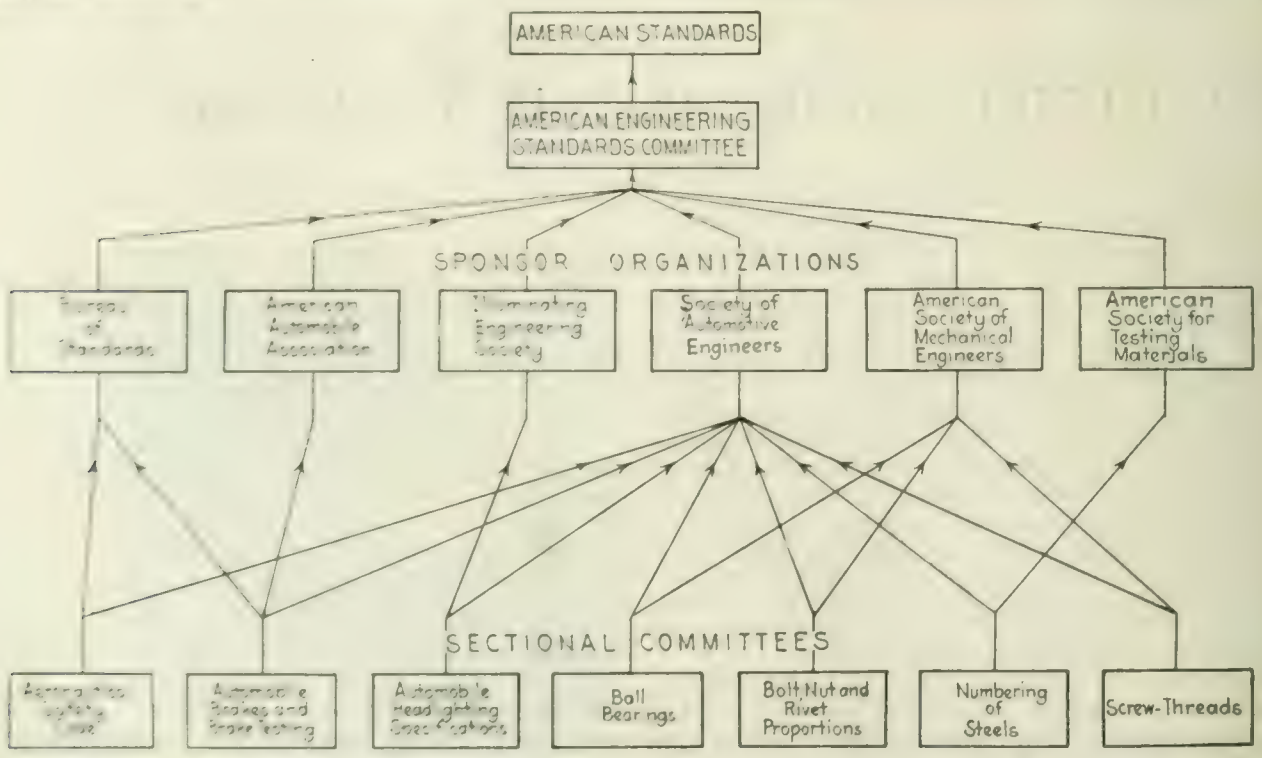
Since the Society became a member of the American Engineering Standards Committee in 1920, it has been designated as a joint sponsor for seven projects. The complete personnel of the sectional committees appointed for these seven projects represents 41 organizations. The accompanying chart illustrates the procedure that will be followed by the sectional committees in obtaining recognition of their reports as American Standards by approval of the respective sponsors and the American Engineering Standards Committee. In addition to the projects for which it is acting as a joint sponsor, the Society is represented on the following sectional committees, whose work will affect partially the automotive industry:

Code on Colors for Traffic Signals
Gears
Insulated Wire and Cables
Machine-Tool Safety Code
Methods of Testing Timber
Pipe Flanges and Fittings
Use, Care and Protection of Abrasive Wheels

WIRE CLOTH TO BE STANDARDIZED

Tentative Report Submitted to Wire Cloth Users and Manufacturers for Comment

Shipments of wire cloth direct from the manufacturers' stocks, quicker deliveries and an increase in the sources of supply are cited as probable results of the adoption in future practice of a proposal, submitted by E. W. Weaver, of the Parts and Fittings Division, to limit wire cloth for oil, gaso-



Sectional Committees of the American Engineering Standards Committee of Which the Society Is a Member and the Other Sponsor Organizations Associated with It on Them

line and water strainers to 10 meshes. The proposal, given in the accompanying table, has been sent to the engineering departments of passenger-car and motor-truck builders for comment. It is expected that it will be ready for Standards Committee action at the January meeting.

PROPOSED S. A. E. STANDARD FOR WIRE CLOTH

Mesh	Diameter of Wire, In.	Size of Opening, In.	Mesh	Diameter of Wire, In.	Size of Opening, In.
8	0.028	0.097	45	0.0095	0.0130
10	0.025	0.075	50	0.0090	0.0110
12	0.023	0.060	60	0.0080	0.0090
14	0.020	0.051	70	0.0070	0.0073
16	0.018	0.044	80	0.0060	0.0068
20	0.016	0.034	90	0.0050	0.0059
24	0.015	0.027	100	0.0040	0.0055
30	0.013	0.021	120	0.0040	0.0043
35	0.011	0.018	150	0.0030	0.0037
40	0.010	0.015	200	0.0023	0.0027

Mesh denotes the number of openings per inch.

Double-crimped wire shall be used and woven so as to make square openings.

The variation in the number of wires per inch shall not exceed 3 per cent. The variation in the diameter of the wire shall not exceed the following limits:

	In.
Up to and including 16 mesh	0.0030
From 20 to 50 mesh	0.0020
From 60 to 100 mesh	0.0010
Above 100 mesh	0.0005

The wire composition shall be definitely specified. Usual practice is to specify steel wire up to 16 mesh, brass wire from 20 to 100 mesh and phosphor-bronze or monel-metal wire above 100 mesh.

The weave shall be what is known as "plain," except that wire cloth in meshes 80 and finer may be "twilled."

STANDARD FRAME-WIDTHS SUGGESTED

Feasibility of Standardizing Motor-Truck Frames Open to Discussion

The Frames Division has been enjoying more than its share of differences of opinion since the standardization of motor-truck frames was undertaken early in the year. The recommendation now under consideration is given in the accompanying table, the side-rail thickness and the chemical composition having been omitted from the original proposal because of adverse criticism received, quotations from which are given below:

PROPOSED STANDARD FOR MOTOR TRUCK FRAMES

Truck Capacity, Tons	Frame Width, In.			Nominal Side-Rail Depth, In.	Actual Side-Rail Depth, In.
	Straight	Offset			
		Front	Rear		
Speed Wagons	32			5	$4\frac{5}{8}$
$\frac{3}{4}$ to $1\frac{1}{2}$	34	31	34	6	$5\frac{1}{2}$
2 to $2\frac{1}{2}$	34	31	34	7	$6\frac{1}{2}$
3 to $3\frac{1}{2}$	38			8	$7\frac{1}{2}$
Over $3\frac{1}{2}$	38			9	$8\frac{1}{2}$

The classification of vehicles on a nominal basis of capacity rating for a structural standard of this type is entirely wrong and meaningless. Unless the Society wants to tackle the problem of defining the meaning of a 3-ton truck, the use of the term is certainly of no value from a technical standpoint. Commercial usage has destroyed whatever value such a method of rating has had.

With regard to the chemical composition, while it may be argued that frames are made for stiffness rather than for strength, and that for adequate stiffness plain carbon-steel is sufficient, there are some who take issue with that general principle as applied to motor-truck construction.

The suggestion to standardize the inside height of the frame by ½-in. increments is in order. It certainly is desirable to have frames of 5½ or 6-in. inside height, as this part of the frame die is invariably solid and may be used in connection with materials of various thicknesses. We have used a 4½-in. inside height of frame for approximately 10 years on light models, but the thickness of stock has been varied to suit the particular lengths required. This sort of standardization is the kind we should work on.

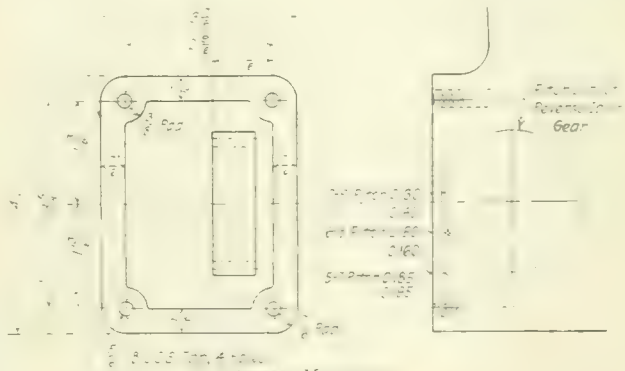
Builders of trucks should have the choice of thickness, which would not interfere with dies and give a better range of strength.

TIRE PUMPS INTERCHANGEABLE

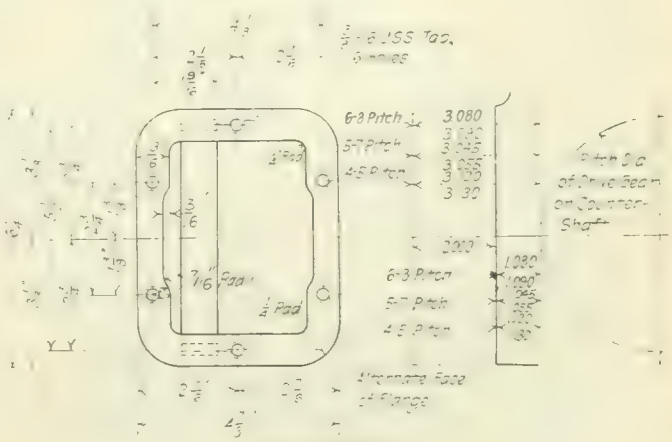
Transmission and Truck Makers Adopt S. A. E. Standard Transmission-Type Mountings

After the S. A. E. Standard for transmission-type tire-pump mountings was adopted in 1919, difficulty was experienced in designing transmission cases to accommodate various makes of tire-pump. In order to obtain complete interchangeability, the Transmission Division planned to extend the standard shown on p. E1 of the S. A. E. HANDBOOK to specify the largest space that the tire-pump should require, and appointed H. W. Sweet, of the Brown-Lipe Gear Co., to submit a recommendation based on the practice existing at that time.

At the October meeting of the Transmission Division Mr.



SMALL MOUNTING



LARGE MOUNTING

[illegible] practically ceased during the last 2 years and that no need for further standardization now exists.

FLEXIBLE-DISC PROPOSAL CHANGED

Requirements of Over 175 Sizes Used in Present Practice Met by 21 Standard Sizes

On Oct. 18 the Subdivision on Flexible Discs held a meeting in Detroit at which the original proposal printed on p. [illegible] of the July, 1923, issue of THE JOURNAL was revised. On Oct. 19 the Parts and Fittings Division also held a meeting in Detroit at which the revised proposal, given in the accompanying table, was approved for adoption as S. A. E. Recommended Practice. During the Division meeting it was stated that if the recommendation were adopted in future practice, there would be a reduction from 175 to 21 in the number of sizes of disc used.

At the Subdivision meeting, which was attended by E. W. Templin and E. G. Kimmich, of the Goodyear Tire & Rubber Co.; A. P. Hamilton, of the Merchant & Evans Co.; J. W. B. Pearce, of the Spicer Mfg. Co.; C. A. Schell, of the Thermoid Rubber Co.; Ira S. Snead, of Snead & Co.; J. C. Sproull, of the B. F. Goodrich Co., and Standards Manager Burnett, revisions of the original proposal, based on the comments that had been received as a result of circularizing it among users and manufacturers, were made.

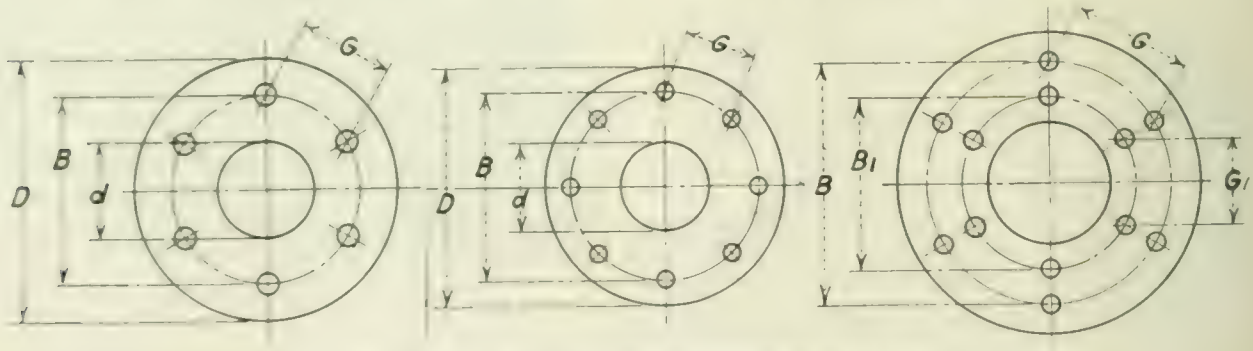
The consensus of opinion was against including the torque ratings because of the number of variables it is necessary to consider when selecting the proper disc for a given installation, such as the linear and angular positions through which the discs revolve, the type of service and the weather.

To aid the users, and to protect the manufacturers against the marketing of inferior discs, it was suggested that a standard minimum test for the material should be included. It was decided to give this matter further consideration.

The 6½ x 5 16, 7½ x 5 16, 7 x 13 32 and 8¼ x 5 16-in. eight-hole discs were added to the proposal to meet the needs of a flexible drive-shaft coupling between the engine and the transmission.

The following changes and additions, based on the present practice of the large producers of automobiles, and on what is considered sound engineering, were made in the original Subdivision recommendation:

(1) The tolerances for the bolt-circle diameters were changed to plus and minus 0.010 in.
(2) The tolerances for the bolt-hole diameters were changed to plus 0.010 in. and minus 0.000
(3) The tolerances for the thickness were changed to plus 0.020 in. and minus 0.000.
(4) The 6 x ¼-in. size was omitted
(5) The inside and bolt-hole diameters for the 6½ x ¼-in. size were changed to 2.500 and 0.438 in. respectively
(6) The inside diameter was changed to 2.500 in. for the 6½ x 5 16-in. size



PROPOSED STANDARD FOR TRANSMISSION-TYPE FLEXIBLE DISCS

Type	Nominal Size	Outside Diameter D ±0.030	Inside Diameter d ±0.030	Bolt-Circle Diameter ±0.010 B	Bolt-Circle Diameter ±0.010 B1	G ±0.010	G1 ±0.010	Bolt-Hole Diameter +0.010 -0.000	Thickness +0.020 -0.010
Six-Hole	6 x 5/16	6.000	2.250	4.625		2.313		0.438	0.313
	6 x 3/8	6.000	2.250	4.625		2.313		0.500	0.375
	6½ x ¼	6.500	2.500	5.000		2.500		0.438	0.250
	6½ x 5/16	6.500	2.500	5.000		2.500		0.500	0.313
	7 x ¼	7.000	2.750	5.250		2.625		0.500	0.250
	7 x 5/16	7.000	2.750	5.250		2.625		0.500	0.313
	7 x 3/8	7.000	2.750	5.250		2.625		0.500	0.375
	7½ x 5/16	7.500	2.750	5.625		2.813		0.500	0.313
	7½ x ⅜	7.500	2.750	5.625		2.813		0.500	0.375
	8 x 5/16	8.000	3.000	6.000		3.000		0.625	0.313
	8 x ⅜	8.000	3.000	6.000		3.000		0.625	0.375
	8½ x 5/16	8.500	3.000	6.250		3.125		0.625	0.313
	8½ x ⅜	8.500	3.000	6.250		3.125		0.625	0.375
	9 x ⅜	9.000	3.250	6.500		3.250		0.625	0.375
Eight-Hole	6½ x 5/16	6.500	2.750	4.750		1.818		0.375	0.313
	7½ x 5/16	7.500	2.750	5.625		2.153		0.438	0.313
	7½ x 7/16	7.500	2.750	5.625		2.153		0.438	0.406
	8¼ x 5/16	8.250	3.000	6.500		2.487		0.500	0.313
Double-Row	9½ x 5/16	9.500	3.250	8.000	5.750	4.000	2.875	0.500	0.313
	9½ x ⅜	9.500	3.250	8.000	5.750	4.000	2.875	0.590	0.375
	10½ x ⅜	10.500	4.250	8.500	6.000	4.250	3.000	0.500	0.375

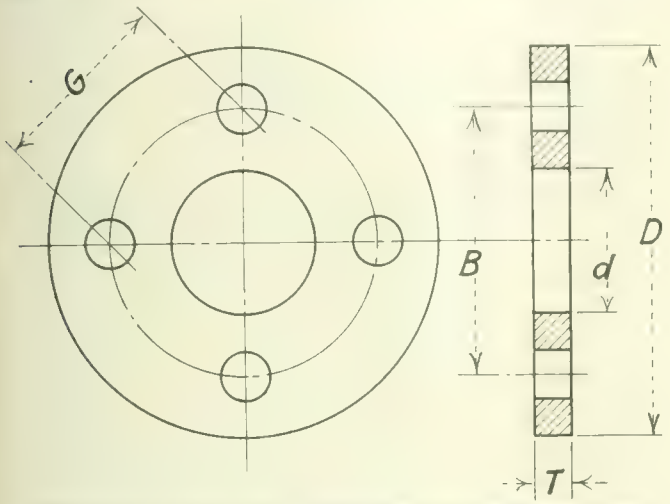
* This size of disc is used principally for coupling between engines and transmissions of passenger cars.

(7) The inside diameter was changed to 2.750 in. for the 7 x 5/16-in. size

(8) The following nominal sizes were added:

6 x 5/16	7 x 1/4	8 x 5/16
6 x 3/8	7 x 3/8	8½ x 5/16

As double-row discs of large diameter are used for severe service, it was considered advisable to include in the recommendation the 9½ x 5/16, 9½ x 3/8 and 10½ x 3/8-in. double-row discs.



PROPOSED STANDARD FOR GENERATOR AND MAGNETO TYPE FLEXIBLE DISC

Nominal Size	Outside Diameter D ±0.030	Inside Diameter d ±0.030	Bolt-Circle Diameter B ±0.010	G ±0.010	Bolt-Hole Diameter +0.010 −0.000	Thickness T +0.020 −0.010
2¾	2.750	1.000	1.875	1.326	0.328	0.250
3½	3.500	1.250	2.500	1.768	0.328	0.250
3½	3.500	1.250	2.500	1.768	0.328	0.313

To complete the proposal, it was recommended that smaller discs, used for generators and magneto drives, should be included. The disc dimensions shown in the accompanying table were suggested with the understanding that final action should be based on the comments of users and manufacturers.

PRESENT MOUNTINGS SUFFICIENT

Transmission Tire-Pump Mountings Satisfactory for Motorbus Generators

The Transmission Division has recommended that the present S. A. E. Standard for Transmission Tire-Pump Mountings shown on p. E1 of the S. A. E. HANDBOOK, shall be used for motorbus generator and starting-motor mountings. This action, based on the experience of several transmission makers, was taken in view of suggestions received by the Society to the effect that, because of the demand for motorbus generators of greater capacity than is needed in passenger-car engineering, and the lack of available space when mounted on the engine, special mountings should be standardized for motorbus applications.

BOLT-HEADS, NUTS AND WRENCH OPENINGS

Variations in Dimensions Analyzed and Tentative Recommendations Made

In March, 1922, the Sectional Committee for the Standardization of Bolt, Nut and Rivet Proportions was organized under the rules of procedure of the American Engineering Standards Committee by the American Society of Mechanical Engineers and the Society of Automotive Engineers acting as joint sponsors. A subcommittee, designated as No. 2, was appointed to report on wrench bolt-heads and nuts and, after obtaining and analyzing data covering practice in the United States and abroad, has submitted a tentative report for circularizing. Although the data in this report have been given some publicity, the subcommittee desires a careful review of them by all industries toward submitting whatever criticisms they may have to offer.

Included in the report is an analysis of the variations in dimensions for corresponding bolt sizes that exist generally throughout the industry in the United States, England and Germany. The recommendations in the report include dimensions of the heads, heavy nuts and jam nuts for rough and finished square and hexagonal bolts, finished light nuts, finished hexagonal and square cap-screws and their corresponding wrench openings.

The dimensions for the heavy and light nuts correspond to those used by some manufacturers in their present practice, but the subcommittee states that it has not been able to prepare tables of sizes that would meet the present practice of all industries, although the tendency in recent years has been toward more economical use of material for screws, bolts and nuts such as those made to the S.A.E. Standard. This part of the report is submitted particularly for consideration looking toward the use by all industries of a single standard for bolt-heads and nuts, using only light-nut dimensions for ⅝-in. bolts and smaller except that the width across flats of the 7/16-in. bolt be made 11/16 in. instead of ⅝ in. The tables of proposed dimensions, however, include the heavy nuts for the ⅝-in. size and smaller and the ⅝-in. width across flats for the 7/16-in. size.

The proposed tolerances are from basic to minus for all bolt-heads and nuts and from basic to plus for wrench openings to provide sufficient wrench fit clearance. The amounts of tolerance have been selected for "rough" and "finished" products, "rough" finish pertaining to stock made by cold or hot pressing, punching or forging, but not to semi-finished products made by any process. The "finished" class of products pertains to bolt-heads and nuts that are machined all over and includes those that are semi-finished by any process.

After the report has been approved by the Sectional Committee, it must be submitted to and approved by the sponsor societies before it can be finally approved by the American Engineering Standards Committee as American Standard. It is very desirable, however, that the proposal be carefully reviewed by the industries before a final report is drafted. Criticisms by all those interested in the manufacture and use of these products are solicited. Copies of the subcommittee's report in pamphlet form may be obtained on request to the American Society of Mechanical Engineers, 29 West 39th Street, New York City, and written comments on the report should be addressed to the Chairman of Subcommittee No. 2, Sectional Committee on Bolt, Nut and Rivet Proportions, at the same address.

"COACH" CRITICIZED AS BODY NAME

Recommendation of Passenger-Car Body Division To Be Reconsidered

As a result of the publication in the November issue of THE JOURNAL, on p. 417, of the report of the Passenger-Car Body Division covering "coach" as a standard type of body and its circularization among the body and passenger-car builders, considerable criticism has been submitted. The definition for "coach" proposed by the Division is

> An enclosed single-compartment body, similar in general appearance to a short sedan, with two close-coupled cross-seats for four passengers. There is a luggage compartment or space for a trunk at the back of the body. There is no glass in the rear quarters. The conventional type has two doors only, the forward seat being divided and the right-hand seat tipping forward to give access to the rear cross-seat. Some models have two doors on the right-hand side, there being two fixed cross-seats.

BODY NAMES USED FOR THE FOUR-DOOR FIVE-PASSENGER COUPE TYPE OF BODY DESCRIBED

Cadillac	Coupe
Chandler	Touring Sedan
Cleveland	Two-Door Sedan
Dodge	Four-Passenger Coupe
Essex	Brougham
Franklin	Coach
Hupmobile	Coach
Jewett	Four-Passenger Coupe
Lexington	Two-Door Sedan
Franklin	Brougham
Hudson	Coach
Jordan	Brougham
Lincoln	Coupe
Marmon	Coach
Nash Four	Carryall
Oakland	Five-Passenger Coupe
Oldsmobile	Brougham
Paige	Coupe-Brougham
Packard	Five-Passenger Coupe
Peerless	Coupe-Brougham
Studebaker	Touring-Sedan
Stutz	Coupe
Willys-Knight	Brougham

The close-coupled sedan type of body has two fixed cross-seats, four doors, windows in the rear quarters, a luggage compartment in the rear and is constructed of metal above the belt-line. With the exception of the luggage compartment in the rear, this type of body is variously called a "close-coupled sedan." The names used for this body by the different companies producing it are given in the following list:

BODY NAMES USED FOR THE SEDAN TYPES OF BODY DESCRIBED

Buick	Bruette
Hupmobile	Brougham
Jordan	Four-Door Brougham
Marmon	Four-Passenger Sedan
Maxwell	Petite Sedan
Nash Six	Four-Passenger Coupe
Overland	Champion
Star	Brougham
Willys-Knight	Coupe-Sedan

It will be noticed that about one-third of the names used are unreasonable misnomers. As an example, brougham, which seems to be as popular as any of the names, refers to a two-passenger covered type of body that is similar to the limousine except that the roof extends only over the portion of the body occupied by the passengers.

The use of "coach" is quite unreasonable as it refers to an obsolete type of body although the present motorbus might be considered to have rightly inherited that designation.

The committee that has been engaged in preparing recommendations of the Passenger-Car Body Division have been relieved by the Division members for consideration. Extracts of several are printed hereinafter as they will be found of special interest.

The name "coach" is very good for a two-door job, with the front seat turning forward, but for a three-door job it should be called a four-passenger coupe.

Our recommendation is to use the term "close-coupled sedan" with two-three or four doors as the case might be.

We recommend that the coach type of body be limited to the two-door, four or five-passenger body with entrance to the rear cross-seat made possible by tilting forward the right-hand front seat.

I do not approve using the word "coach" as recommended. The word "coach" in the body-building trade has always had a definite meaning in the past and is used in the same way now in advertising by body builders. According to this practice, a coach is any type of closed body, coach-work being understood as the building of closed bodies, coach-work never having been applied to the building of open bodies. I believe the word "coach" should remain a general definition for any type of closed body.

On account of the unlimited number of variations that can be made of body construction to create different body types, I do not think that any positive results can be obtained by trying to standardize names to define different body types. In place of a standard name for closed bodies, I would prefer seeing the car builder use whatever name he wishes. He will do so anyway. Names to distinguish different models produced by the same builder could be effectively taken care of by using names similar to what are used on Pullman cars.

A coach is really not the name of a body at all, but refers to an entire vehicle. Moreover, the accepted definitions of the word are very broad and do not apply to any particular type of vehicle, although in the early coaching days it did have some reference to a type of vehicle driven with two span of horses in which passengers rode on top.

I personally do not think that the Society should sanction the standardization of a word that already has a very definite meaning in the English language and arbitrarily set thereto a new definition. I think we should encourage the development of new names for types of automobile bodies which would be characteristic and descriptive of the type of body in question.

The naming of bodies by various sales organizations has brought about a condition that is almost an endless task to unravel. As an example, I have been working on a close-coupled sedan type of body having two fixed cross-seats for five passengers equipped with four doors and with a deck on the rear for a trunk. It is the desire of the engineering department to call this a sedan type of body and describe it as close-coupled with two fixed cross-seats and equipped with four doors. The sales department insists on calling this a brougham, primarily on account of the fact that they feel that the general public would accept it as a brougham because the Jordan Motor Car Co. so defines it to the public at large.

It occurs to me that the engineers have a very serious problem on their hands in trying to educate the sales department as to the proper body nomenclature.

The term "coach" as now applied seems to refer to a cheaper type of body than built by the average company.

It appears to us that much more has been covered in the definition than the word "coach" implies. The

name indicates a two-door, enclosed, single-compartment body, with construction and appointments of a comparatively low grade; whereas, there exist two, three and four-door types of enclosed, single-compartment body, having high-grade construction and appointments throughout. To cover these types of body by the word "coach" appears very misleading to us.

The S.A.E. Body Nomenclature has really assumed definite shape and is forming a basis for a standard group of names that will at least be used by an important section of the industry and bodies so designated will be recognizable in advertisements or in technical writing without further explanation.

It is inexpedient to pervert the generic term "coach" to designate a single type of body, unless it be applied to the large motorized public-passenger vehicles that are being operated now in much the same manner as the former road or stage coach. Thirty years ago there was no doubt in the mind of any coach builder as to what was meant by a coach.

Now it is apparently intended that the term shall serve as a catch-all for the sundry modifications of the close-coupled body. Disregarding the matter of appropriateness, the proposed term fails to meet the requirement of utility if it will not be used, even after adoption by the Standards Committee. The name "coach" having been appropriated by an enterprising company and having come to be recognized as its particular appelation, who think that it will ever be accepted by the other car-builders as a group. Most companies building identical bodies have scoured the dictionaries and realms of fancy for a different name.

Practically none of the body names now in use represents the original concept of those names, but certain definite ideas have become instilled in the mind of the great motoring public of America. Regardless of the fact that coupe and sedan do not signify what these names originally did, motorists do recognize these two types. Why could not any of the miscellaneous group which it is proposed to list under "coach" be designated more clearly as coupes or sedans, modified according to the seating and door provisions? Thus, three-door sedan, if there are three doors and two cross seats. The two-door types may be designated as coupes, with the passenger-carrying capacity indicating readily the seating arrangement; the four-passenger coupe suggests immediately the staggered-seat job with an occasional seat folding into the cowl; the five-passenger coupe indicates a full cross-seat in the rear and two individual front seats. Is it not pretty close to selling a car "under false pretenses" to designate these bodies as "broughams" or "touring sedans" or some other classification to which the body is not entitled?

CARRIAGE-BOLT PRACTICE SIMPLIFIED

Sectional Committee on Bolt, Nut and Rivet Proportions Submits Report

With the organization of the Sectional Committee on the Standardization of Bolt, Nut and Rivet Proportions, sponsored by the American Society of Mechanical Engineers and the Society of Automotive Engineers, the carriage-bolt standardization that had been undertaken by the Screw-Threads Division was referred to the Subcommittee No. 5 appointed by the Sectional Committee to consider the standardization of carriage bolts. The personnel of this subcommittee is:

E. Burdsall	Russell, Burdsall & Ward Bolt & Nut Co.
M. C. Horine	International Motor Co.
W. M. Horton	Kirk-Latty Mfg. Co.
R. Plumb	Buffalo Bolt Co.
C. B. Segner	Domestic Engine & Pump Co.
E. P. Stahl	Hyatt Roller Bearing Co.

The proposed standard, adopted by the Sectional Committee in January of this year, was based upon the dimensions and proportions of the various kinds of carriage-bolt used in current practice that were tabulated from data collected by the leading bolt manufacturers. The original Subcommittee report included dimensions for seat bolts, but these were eliminated by the Sectional Committee because the dimensions for the head were practically the same as for the step and the elevator bolts.

The dimensions included in the report were determined by definite formulas based on the body diameter. In addition to the dimensions given in the accompanying table, the Division recommends that the radius under the bolt head for diameters up to and including ½ in. should be 1/32 in. and for over ½-in. diameters, 1/16 in.; that the tolerances for the head for diameters up to and including ½ in. should be plus or minus 0.010 in., and for over ½-in. diameters, 0.015 in.; and that the angle of the counter-sunk head carriage-bolts should be 110 deg.

PROPOSED STANDARD DIMENSIONS FOR CARRIAGE BOLTS

Diameter of Bolt	Common Carriage			Button-Head Carriage		Fin-Neck Carriage				Ribbed Carriage			Elevator Bolt			Step Bolt		
	D	*H*	*L*	*D*	*H*	*D*	*H*	*X*	*W*	*D*	*H*	*C*	*D*	*H*	*L*	*D*	*H*	*L*
5/16	7/16	3/32	3/16	7/16	3/32	1	64	64	3	7/16		1	1	1/8	16	5/8	1/8	
1/4	3/16	1	7/32	3/16	1		7/64				1	1						
5/16	11/16	5/32	1/4	11/16	5/32		9/64	1	1	1		16	1 1/16		1/4	1	5/32	1/4
3/8	13/16	3/16	5/16	13/16	3/16	1	11/64	11/64	5/32	1	7/32	1/4	1 1/4		32	1 1/16	3/16	9/32
7/16	15/16	7/32	5/16	15/16	7/32	1	13/64		3/16	1		1/4				1 1/4	7/32	5/16
1/2	1 1/16	1/4	11/32	1 1/16	1/4	1 1/16	15/64	3/16	1/8	1 1/16		1/4				1 5/16	1/4	
9/16	1 3/16	9/32	3/8	1 3/16	9/32					1 3/16		5/16						
5/8	1 5/16	5/16	13/32	1 5/16	5/16					1 5/16		3/8						
3/4	1 7/16	3/8	15/32	1 7/16	3/8					1 7/16		7/16						
7/8	1 9/16	7/16	17/32	1 9/16	7/16					1 9/16		1/2						
1	2 1/16	1/2	1/2	2 1/16	1/2					2 1/16		9/16						

All dimensions in inches

COMPRESSION FITTINGS RECOMMENDED

Parts and Fittings Division Approves Original Subdivision Report as Revised

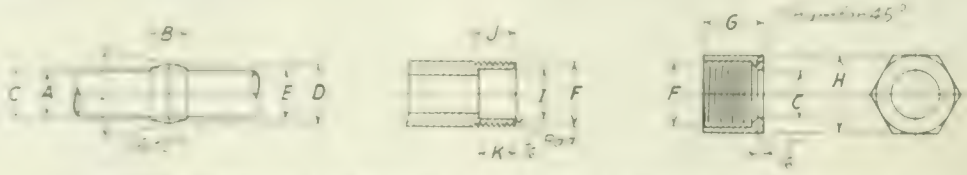
Agreement on the standardization of fuel and lubricating pipe fittings of the compression type, later confirmed by the Parts and Fittings Division, was reached at a special meeting of the subdivision on Fuel and Lubrication Pipe Fittings, attended by W. H. Hollister, of the Imperial Brass Co.; W. J. Outcalt, of the General Motors Corporation; W. G. Wetherby, of the Blue Metal Products Co.; C. S. Kellum and F. W. Berck, of the Commonwealth Brass Corporation; W. S. Chilman, of the McRae & Roberts Co., and C. A. Hill, of the Mueller Metals Co.

The recommendation, which is to be submitted to the Standards Committee for adoption as S. A. E. Recommended Practice, was developed by the subdivision consisting of W. H. Hollister and W. J. Outcalt. The original recommendation, published in the June, 1923, issue of THE JOURNAL, p. 581, was not acted on at the Standards Committee Meeting in June, however, because of the large number of criticisms received.

The recommendation is given in the accompanying tables. The revisions made in the original recommendation taken individually are of minor importance; but collectively they represent a careful refinement and a correlation of corresponding dimensions for similar parts.

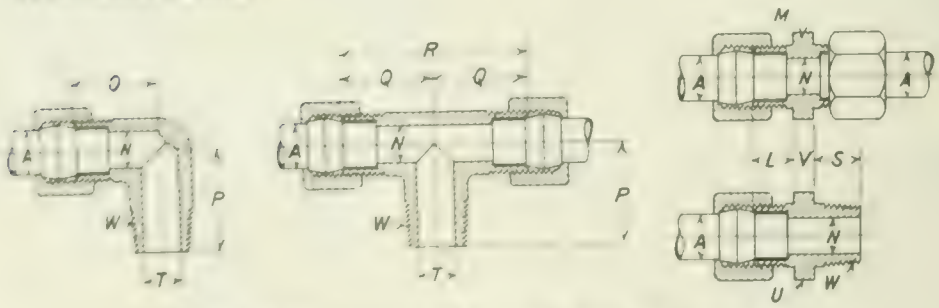
SHEET STEEL COMMITTEES CONSOLIDATED

To coordinate the work of the American Society for Testing Materials and the Society of Automotive Engineers in the standardization of sheet steel, arrangements were com



PROPOSED DIMENSIONS FOR COLLARS, NUTS AND STRAIGHT THREADED-ENDS

Tubing Diameter A	B	Collar Bore C Maximum	Collar Bore C Minimum	D	Small Diameter of Taper E	F	G	H	I ±0.002	J Minimum	K
		0.130	0.126		0.140				0.136		
		0.195	0.191		0.205				0.196		
		0.270	0.255		0.269				0.261		
		0.335	0.321		0.335				0.328		
		0.388	0.384		0.398				0.391		
		0.547	0.513		0.527				0.531		



PROPOSED DIMENSIONS FOR ELBOWS, TEES AND UNIONS

Tubing Diameter A	L	Diameter of Hexagon M	N	O	P	Q	R	S	T	Diameter of Hexagon I	V	W

THOSE WHO ATTENDED THE MEETING OF THE IRON AND STEEL DIVISION AT PITTSBURGH ON OCT. 12, 1923

pleted at the October meeting of the Iron and Steel Division held in Pittsburgh whereby the entire personnel of the Sheet Steel Subcommittee of the American Society for Testing Materials has been appointed on the Sheet Steel Subdivision of the Standards Committee of the Society. The personnel of the Subdivision as it now stands is:

W. C. Peterson, *Chairman*,	Formerly with the Atlas Steel Corporation
W. J. Beck	American Rolling Mill Co.
W. E. Cougherty	Allegheny Steel Co.
J. B. Dailey	General Motors Corporation
J. M. Darke	General Electric Co.
C. N. Dawe	Studebaker Corporation of America
F. C. Elder	American Steel & Wire Co.
F. Walter Guibert	Formerly with the Interstate Iron & Steel Co.
W. A. Irvin	American Sheet & Tin Plate Co.
G. T. Kelly	Edward G. Budd Mfg. Co.
J. H. Nead	American Rolling Mill Co.
F. E. McCleary	Dodge Bros.
E. W. Upham	Maxwell Motor Car Co.
J. M. Watson	Hupp Motor Car Co.
H. M. Williams	General Motors Research Corporation.

The members formerly on the Sheet Steel Subcommittee of the American Society for Testing Materials are Messrs. Beck, Cougherty, Dawe, Kelly and Williams.

AMERICAN LUMBER STANDARDS

Conference in the City of Washington on Dec. 12 to Act on Basic Report

One of the most important phases of the general standardization movements that have developed in the past few years is that of placing the lumber producing and consuming industries on a more economical basis in handling the product. At the first American Lumber Congress in 1919 steps were taken to inaugurate simplification in general standardization of lumber sizes and grades, the basic purpose being to demonstrate the ability and the purpose of the lumber industry to conduct its business efficiently and with due regard to the interests of the consumers. The Central Committee on Lumber Standards, representing the entire organized lumber trade from the producer to the consumer, was organized early in 1922 following a conference of lumber interests in the City of Washington. A consulting committee was also organized representing the same groups of interests to prepare, in behalf of their respective constituents, appropriate data for the consideration of the Central Committee. R. E. Brown of the Fisher Body Corporation represents the Society on the consulting committee.

William A. Durgin, chief of the Division of Simplified Practice of the Department of Commerce, has called a conference in the City of Washington on Dec. 12 at the request of Secretary Hoover of the Department of Commerce to take action on the recommendations for simplified sizes, nomenclature and trade practices presented in the Recommended American Lumber Standards as reported to the United States Department of Commerce by the Central Committee on Lumber Standards. The Society has been asked to appoint two or more representatives to be present.

The report includes sections dealing with

(1) Standard Lumber Classifications
(2) Standard Grade Names and Classifications
(3) Standard Yard Lumber Sizes
(4) Method of Lumber Measurement
(5) Standard Shipping Weights
(6) Shipping and Other Provisions

The specifications refer for the most part to yard lumber, structural timbers and shop or factory lumber but are of interest as probably being the basis on which standard dimensional or cutting-up sizes will be formulated for the automotive industries.

A report on the species, grades and dimensions of lumber purchased for automotive construction, principally bodies, is being prepared by the Forest Products Laboratories in collaboration with the Hardwood Lumber Standardization Subdivision of the Passenger-Car Body Division of the Standards Committee. It is expected that this report will be presented at the body session of the Society's Annual Meeting in Detroit next month.

WIKANDER SUBMITS FOREIGN PROPOSALS

Sectional Committee Acts on Report of International Conference in Zurich

Reference was made in the September issue of THE JOURNAL on p. 177 to a preliminary report received from Zurich, Switzerland, regarding the International Ball Bearing Standardization Conference that was held in that city on July 9. The detailed report agreed to at a conference in Berlin on Oct. 5, which is based on the report of the meeting in Zurich on July 9, has been received and referred to the Sectional Committee for Ball Bearings under the sponsorship of the American Society of Mechanical Engineers and the Society of Automotive Engineers. There are 10 proposals in all, the first five being definite and the others tentative. The first proposal is toward a definite agreement on outside diameters of ball bearings up to and including the 220-mm. bore in the light series, the 200-mm. bore in the medium series and the 190-mm. bore in the heavy series. The second proposal sets forth the widths for single row annular ball bearings up to and including the 140-mm. bore in the light series, the 120-mm. bore in the medium series and the 90-mm. bore in the heavy series. The third proposal refers to corner radii, the fourth to tolerances and the fifth to double row annular ball bearings. The sixth, seventh, eighth and ninth proposals supplement the first, second, third and fifth proposals respectively and refer to the dimensions for the extension of the series above those in the first proposal. The tenth proposal refers to metric thrust ball bearings.

The Sectional Committee, together with the Ball and Roller Bearings Division and Thrust Ball Bearing Subdivision of the Society's Standards Committee, at its meeting in New York City on Nov. 19 took definite action toward approving the first proposal only, inasmuch as the bearing dimensions included therein are the same as in the existing standards. It was felt, however, that the remaining nine proposals should be given further careful study before they are acted on and they were therefore referred back to the sponsor Societies for this purpose.

This project is practically the first one affecting the automotive industries on which a definite attempt has been made

toward international standardization and it is felt by the members of the committees working on it that there is very good prospect of definite results, although there is still some question in their minds as to how far definite standardization should be attempted internationally. It is probable that revised proposals will be worked out and submitted to the foreign standardization committees before final action is taken by the sponsor Socities in this Country. Much progress has already been made toward better agreement between the several countries as to what the international standards shall be and it is possible that such agreement may be had sooner than was expected.

Much was accomplished by O. R. Wikander, chairman of the Sectional Committee's Subcommittee on Information, who, during his extended trip abroad, was able to confer with the national committees, particularly in Great Britain, Germany and Sweden, and was largely instrumental in bringing about the conference in Zurich last July. He presented considerable first-hand information regarding conditions abroad and the desires of the foreign ball bearing manufacturers relating to the program of standardization that might not otherwise have been available to the Sectional Committee and sponsors if the work had been carried on entirely by correspondence.

RESEARCH AN IMPORTANT FACTOR IN HIGHWAY IMPROVEMENT

(*Concluded from p. 496*)

taken; while the latter should determine the probable amount and character of the future traffic that will use a given highway during the lives of its several component parts.

In connection with the proper allocation of funds for highway construction, it was pointed out that the engineer in charge should base his decision upon considerations of the requirements of the State as a whole, and furthermore that he should visualize potential as well as present needs.

Mr. Hamlin outlined the general conditions for successfully carrying through traffic surveys, mentioned costs of various items and gave examples of past experience. These included a tabulation of surveys.

Motor-Truck Transportation in New England

Correlating motor trucking facilities with those of other transportation systems forms one of the most important factors in the effective handling of freight and passengers. J. G. McKay, of the Bureau of Public Roads, in his report for the committee on highway traffic analysis, gave a statistical treatment of truck transportation as carried by 240 companies operating in the principal New England cities. Of over the 1,000,000 net tons of freight hauled over the Connecticut highway system between September and December, 1922, about 67 per cent was hauled less than 30 miles.

Road Maintenance

The combination of truck and rail, truck and boat and truck, rail and boat services were said to be growing in importance very rapidly. Cooperative arrangements between the operating companies seem to be yielding highly satisfactory results and promise to expedite very greatly terminal freight movement, decrease the volume of freight warehoused, reduce the cost of moving freight through terminals and make the rail delivery time of freight in less-than-carload lots more rapid.

Chairman W. H. Root of the committee on maintenance reported that seven problems were studied during the year and that the outstanding conclusions of the investigations were as follows: corrugations in gravel roads result from excessive traffic and are in no way dependent upon construction or maintenance methods; mulch should be applied in very light courses, preferably late in the season or during the spring, and should not exceed 1 in. in depth; the demand for a light-colored crack-filler has decreased to such an extent that further search is unnecessary; snow removal equipment should be developed that is especially adapted to highway work; guide, caution and danger signs should be standardized to facilitate intercounty and interstate traffic; a uniform system of maintenance accounts would put the maintenance reports on a comparable basis; constantly increasing traffic makes it almost impossible to determine accurately the effect of age on the maintenance costs of highways and the subject is worthy of further and very careful consideration.

Highway Construction Costs

H. H. Wilson, representing the Associated General Contractors of America, stated that the activities and interests of that organization in cooperative work with the Advisory Board are largely confined to investigations upon the items that affect the cost of construction or the business end of construction and designing. He mentioned the following general divisions of the work and reported progress in the consideration of each of them: material supplies; field work force; methods; equipment development; seasonal suspension of work; removable hazards of the industry; and comparative statistical relations.

At the conclusion of the session brief reports were presented from the floor by representatives of the several organizations cooperating with the Advisory Board in research work.

MEETINGS OF THE SOCIETY

AIR TRANSPORT MUST PAY DIVIDENDS

Only Basis on Which Aviation Can Prosper, W. B. Stout Tells Detroit Section

W. B. Stout

Commercial aviation must be made profitable financially if we are to have a stabilized aeronautical industry in this Country. Until an industry can take its place on the basis of earning capacity, it can never be a true success, no matter how many millions of dollars in Government appropriations may be spent in its support. No industry can be classed as permanent that keeps its books in red ink. To make aviation pay dividends, then, is the fundamental problem that must be solved before an American aeronautical industry, in the true sense of that word can exist. These are opinions expressed by W. B. Stout in his illustrated talk before the Detroit Section, Nov. 1.

Commercial aviation must be built upon conditions as they are. It is all very well to dream of days when landing-fields will be plentiful and airplanes will be produced economically in great quantities, but the promoters of tomorrow's commercial aviation must face conditions as they exist and make profits from them. This fundamental must be kept in mind when discussing the probability of establishing the aeronautical industry on a sound basis, according to Mr. Stout.

Just as the development of the automobile itself has carried forward the expansion of the automobile industry, so the future of air transportation depends upon the development of the airship and the airplane. An analogous case is that of motorbus transportation. Long ago it was recognized that urban and interurban transportation of passengers by motorbuses was the coming method, but the motorbus business did not thrive until one organization produced a bus designed especially to operate profitably in this service. Once this was done, motorbus lines sprang up all over the United States and the bus industry became an established fact.

Must Carry Greater Pay-Load with Same Power

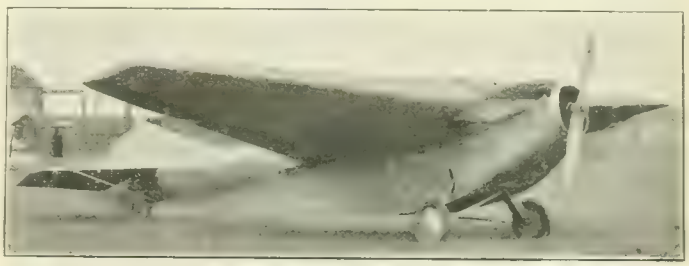
Before airplanes can be expected to pay dividends, they must be designed to carry more pay-load with the engine powers available today. This does not mean that larger planes must be built. If an airplane is doubled in size, its wing area, which represents its lifting ability, is increased only four times but its volume or weight will increase nearer eight times. Lighter-than-air ships, on the other hand, profit from an increase in dimensions. If an airship is doubled in size, its envelope or surface is multiplied four times, but its volume, which represents its lifting capacity, is increased eight times. This is a fundamental difference between the two mediums of air transportation and one that will result in the construction of large airships as opposed to relatively small airplanes.

Safety is the first element in commercial aviation that concerns the average man. Certainly it is the matter of first importance in the mind of the banker or investor who will be called upon to finance the development of air transport. Yet comparatively few people realize that the United States Air Mail is operating over 95 per cent of the days in the year between New York and San Francisco without any serious accidents. The Central Division between Chicago and Salt Lake City recently finished its 106th week of 100 per cent performance on that section. That completes nearly 2 years of service without a forced landing, the planes flying every day and operating on a definite time schedule. Mr. Stout cited this as an example of what can be accomplished by properly organized commercial aviation from the standpoint of safety and regularity.

Inexpensive Construction of Paramount Importance

Mr. Stout emphasized the fact that the commercial airplane of today must be designed so that it can be built cheaply. He distinguished between building and manufacturing, saying that airplanes cannot be manufactured and sold in large numbers at present but must be built along small production lines, just as motorboats are built. For this reason, the present-day commercial airplane must be a very simple structure, built up with the least expensive methods of construction. It must be able to operate the greatest number of hours in the air and spend the least number of hours on the ground. War planes are not adapted to commercial service because they require an excessive amount of repair and maintenance work. Mr. Stout believes that the commercial airplane of the future must be capable of flying 20 hr. per day because there will be more night than day flying. He reported the Air Mail pilots, who flew the night schedules during the late summer, as being more favorable to night flying than to day flying.

Slides were shown of the early types of airplane, including the Wright, Farman, Bleriot and Latham, to illustrate the development of the present-day type of internally-trussed monoplane that Mr. Stout favors. He ended his talk by taking some 60 members to visit his factory where they were shown two metal monoplanes of this design. The one illustrated on this page was in completed condition. It has a wing spread of 40 ft., weighs the same as a small sedan, 1850 lb., and is powered with a 150-hp. engine. Construction of the thick-section monoplane wings from rolled duralumin, formed to give maximum strength and stiffness with minimum weight, has resulted in a structure that weighs only 1.1 lb. per sq. ft. of wing surface. This compares with 1.6 lb. per sq. ft. in the case of the all-metal German Junker monoplane and 2.8 lb. per sq. ft. for the Fokker monoplane that flew from New York to San Diego without stop.



Stout All-Metal Air Sedan

A [illegible] airplane was shown in process of [illegible]. This [illegible] will be powered with a Liberty [illegible] and will carry a load of 1 ton at a speed of [illegible].

FOUR-WHEEL BRAKES PLEASE USERS

C. W. Jacobs Analyzes the Various Designs at Minneapolis Meeting

C. W. Jacobs

Improvement in brake action is imperative to take care of congested city traffic and fuel-eating country hills, according to C. W. Jacobs, service manager of the Pence Automobile Co., Minneapolis. At the Nov. 7 meeting of the Minneapolis Section, Mr. Jacobs presented four-wheel brakes as the best solution of the problem. His paper, An Analysis of Various Four-Wheel Brake Designs, was illustrated by the use of a front-axle brake assembly.

Mr. Jacobs began his analysis by pointing out that mechanically the problem of four-wheel brake installation has been successfully solved, and the only criticism that can be made of it is from a sales point of view.

Internal and External Brakes Contrasted

The first layout discussed was the internal expanding system. This arrangement necessitates fewer operating parts and is possibly the neatest looking of any of the current designs. Theoretically, the brake-bands or shoes are protected from all adverse road and weather conditions, but this is not wholly true in practice.

To eliminate all water, sand and dust from the inside of the drum is impossible and the more closely fitting the protecting shields are made, the harder it is to throw out the small particles of grit that do gain entrance to the interior of the brakes, and frequently the operating pins on internal brakes are found to be badly rusted because of their inaccessibility and consequent lack of lubrication. If drain holes are included in this design they must be small enough so that they do not act as inlets for dirt and moisture, and if small they soon become plugged with dirt from the road and so lose any usefulness they may have originally had.

Theoretically the braking pressure of the internal brake can be made as effective as the external, but working on a smaller area than the external, given the same size drum, and without the wrapping effect of the external, it demands greater braking effort on the part of the operator or longer braking leverages.

The heating of internal brakes has a marked effect upon their efficiency on long grades. It is surprising to note the actual additional movement of the brake pedal on many internal brake designs and what a large percentage of the braking power is lost because the same leverage cannot be exerted on the expanded drum.

Complete protection of front-wheel brakes seems altogether necessary, as external rear-wheel brakes on almost every make of car have for years been subjected to mud, sand, rain and snow without any serious handicap, and the application of this type of brake to the front wheels does not subject it to any worse conditions at the front end than it has at the rear. In fact, the perfect freedom these brakes have for throwing out any particles that do lodge between the drum and the lining tends to keep them clean as far as the braking surface is concerned.

Thermal expansion increases rather than decreases the braking ability of the external brake because as the drum expands it swells toward instead of away from the bands.

Like anything else on an automobile that is to prove mechanically sound, four-wheel brakes must be designed for and built into the particular car on which they are going to operate and not merely attached as an after-thought.

Anchor Block Improves External Braking Power

Discussing the flexible brake-band, Mr. Jacobs pointed out that it cannot be used with impunity on the internal design, although it is ideal for external use. If the band anchor block is placed so that a long portion of the band can be used for forward braking, with the short portion for backward braking, a wrapping effect can be produced on forward braking that is similar in action to a half hitch with a rope, and tremendous braking power is produced at the wheel with comparatively little pedal pressure.

This design is fully permissible with four-wheel brakes where possibly it is not with two-wheel brakes. For example, a brake-band designed alike on all four wheels, with a three-quarter lapping for forward braking and a quarter lapping for backward braking, gives four quarter-laps for backward braking, which is equal to the two half-laps of the conventional two-wheel system. But it has increased the forward braking ability by four three-quarter-laps, instead of the possible four half-laps. This is an increase in braking area of 50 per cent over the four-wheel braking system using half-laps, and an increase of 150 per cent over the conventional rear-wheel brakes.

These results are brought about because the greatest braking power is produced by that portion of the band which is behind the anchor block and in the direction of rotation of the wheel, while that portion of the band which is ahead of the anchor block in the direction of rotation is not exerting its full ability because it is being lifted off the drum instead of being wrapped around it.

If this long portion of the band has one or two intermediate points of adjustment, it then allows four or five places to adjust on each wheel which permits an accurate, well-fitted band that, because of its flexibility, will give a full contact on every brake application besides eliminating the necessity for a fully equalized layout.

Unequalized Designs More Practical

With reference to the equalized system, the speaker reminded his audience that complete or perfect equalization of four or even of two brakes is almost impossible to achieve in actual practice, because of the difficulty of keeping every part, pin and bearing working with the same freedom of drag or friction. When one part of the mechanism fails to work as freely as all the other parts, equalization is entirely upset and the equalizing bars or shafts function in theory only. In an equalized system the danger exists that, if one part of the operating mechanism fails, the entire braking system is made inoperative, because no place remains at which to get a foothold to exert leverage on the rest of the layout.

In the case of an unequalized design, the adjustment of each brake must be exactly similar to that of all the others and this requires a close and accurate adjustment of all four. Tests have shown that these adjustments can be maintained for remarkably long periods of time without attention. This design possesses an inherent safety because some part on each brake would have to fail before entire braking power would be lost.

Future Brakes Probably Hydraulic

The hydraulic method of brake application is by far the neatest looking of any yet designed, is capable of being made to exert tremendous pressure and, for equalization of braking pressures, approaches a point of perfection. Mr. Jacobs made the point that, as in all equalized types, a failure of one pipe makes the entire system inoperative. Unlike other equalized types, however, the hydraulic method can be designed for the differential action of the front brakes by by-passing a certain amount of oil when the

wheels are turned and thus reduce the braking pressure on the outside wheel. This method of applying brake pressure is, however, subject to weather conditions and care must be taken to keep the viscosity of the fluid high enough to operate satisfactorily with all temperature changes. The operating fluid is usually some mixture of glycerine and oil in varying proportions. Water is never used because of the possibility of rusting and freezing.

Although the advantages of the present hydraulic systems must be discounted somewhat because of the extreme care necessary to maintain them in perfect operation and the difficulty in getting them serviced, Mr. Jacobs believes that a development of the hydraulic idea will probably be the leading method of brake application in the future.

Mr. Jacobs concluded his interesting analysis with the statement that altogether four-wheel brakes are one of the finest developments ever added to the automobile and that, in his opinion, not one sensible, logical, reasonable argument can be used against their universal adoption.

Questioned about trouble due to dragging of the band on an external brake, Mr. Jacobs replied that such trouble is likely to occur if the anchor block is not used. With the anchor block, the spring control is always pulling the spring band away from the drum.

With half-laps on the average set of brakes, in almost all cases, the lining of the upper half, if properly adjusted, wears out more quickly than the lower half; but, as Mr. Jacobs pointed out, the lower half, that is, the brake nearer the front end, wears first.

The user's experience is a valuable guide. The increased braking ability and surer control of cars equipped with four-wheel brakes has been found to be appreciated by their drivers. A test made on Michigan Avenue, Chicago, showed that the car with four-wheel brakes can make more headway than the car with brakes on only two wheels. While the other cars were going a block, the test car went a block and a half without more danger of accidents and complying with all the traffic rules.

The next meeting of the Minneapolis Section will be held at 8 o'clock on the evening of Dec. 5, in the Manufacturers Club room, Builders Exchange, Second Avenue, South, between Sixth and Seventh Streets, Minneapolis.

GATHERING OF THE AERONAUTIC CLAN

Spirited and Valuable Discussion Before Metropolitan Section

E. P. WARNER

The most representative meeting of aeronautic engineers for at least 3 years discussed the present status and prospect of aircraft, with reference to the operation of civilian air-routes and of non-Governmental individual craft. Several members traveled long distances to hear Prof. E. P. Warner, the Society's vice-president for aviation and associate professor of aeronautical engineering at the Massachusetts Institute of Technology, discuss Civil Aviation in 1923. In addition to the paper that had been prepared in advance of the meeting, he spoke extemporaneously at some length, one of his major premises being that all figures which have been collated indicate that the special hazard of air transport resides primarily in poor maintenance, poor piloting or poor airplane design and not in the inherent nature of flight. The accidents in the Air Mail Service are so few that they can be deemed virtually non-existent, although that service operates under conditions that would be considered impossible for any passenger-carrying air-line in the world. In England there has been only one accident involving serious injury to a passenger on any commercial line in the last 2½ years, during which time nearly 5,000,000 passenger-miles have been flown. A Dutch company has covered very nearly 1,000,000 airplane miles without a serious accident, and at least one French line has a perfectly clean record. The crux of Professor Warner's argument was that to gain public confidence the airplane must be operated on a large scale for a considerable period of time. The difficulty is to enlist a sufficiently large amount of capital to support such an undertaking. There is very little travel relatively by air today and there will not be much more in his opinion so long as the public idea of an air-line consists of a small airplane traveling each day on each of three or four routes in the Country. The maintenance of ground engineering and mechanical staffs at a few fields for the purpose of welcoming a few airplanes each day is outside the realm of practical business procedure. Professor Warner thought that as a general thing the granting of subsidies to airplanes, which is common practice in Europe, will not be helpful in the long run. The Government should extend assistance in this Country by providing ground organization facilities and in similar ways. The establishment of landing-fields is obviously a Governmental function. The Air Mail Service, which has an unequaled record, should be extended by Governmental operation and also through contracts with civilians. The greatest contribution to aeronautics during the last 3 years has been that of the Air Mail Service, including, of course, transcontinental flight by day and by night.

Professor Warner said that no greater number of passengers are carried by aircraft in Europe today than were carried 2 years ago. He believes that the relatively high cost of travel is not an impediment. In fact, considering the depreciation of European currency, air travel is in some cases cheaper than rail travel. The supposed danger is what keeps the public from flying. Statistics are not enough to obviate this, direct contact with large-scale flying being necessary. The speaker deplored the fact that the principal things the public reads about aircraft is stories of great altitude and very fast flights. He stigmatized aircraft stunting and acrobatics as the curse of commercial use of aircraft. One thing that makes flights of the Shenandoah effective is the fact that she cannot be stunted.

Alexander Klemin in a written communication advocated establishing mail and express service before concentrating upon the expansion of passenger service.

W. B. Stout in a breezy letter stated that aviation must "go out and get" for itself. No aircraft enterprise is profitable now, the present airplanes not being suitable. A commercial plane must be developed. The enactment of regulations will not develop aviation. Machines must be able to operate from 6 to 20 hr. per day and have marked ability to fly, climb and carry freight. The way must be paved with present conditions recognized and accepted. A sizable portion of the public is now willing to pay to fly.

R. H. Upson advocated "making haste slowly." The public must be given time to accept aircraft in a wholehearted way. In the meantime, much progress can be made by improving aircraft as well as securing thoroughly reliable engines therefor. Flying must be maintained consistently at night. The future of aviation is in the hands of a few adventurous spirits, and commercial flying will come with a rush when it does come.

C. F. Redden concurred in the view that what will establish aviation is confidence. Thoroughly well-maintained flights over established routes alone will serve the purpose. The perfect aircraft will not arrive in any shorter time relatively than did the present highly-developed automobile. Aircraft will be developed by the operating organizations and men. The flying-boats maintained by the company with which Mr. Redden is associated have traversed the water between Cleveland and Detroit 500 times, carrying 4000 passengers, without trouble. Mr. Redden believes that at no time during the operations of this company would its

business have been increased much by reducing the price of flights to passengers. He is firmly of the opinion that the [illegible] to the maintenance of civilian air-routes is [illegible] and that as a result of their work the aircraft will be improved in construction. In the service that has been maintained by the company for over 3 years, [illegible] passenger-miles have been flown, over [illegible] persons having been carried, with only 1 serious accident. Mr. Kettler believes that a successful operating company can be organized anywhere in this Country today, flying having been proved to be safe. He feels that there is no doubt as to the desire of the public to fly.

Augustus Post urged the necessity for establishing additional landing-fields. He mentioned briefly a considerable amount of freight carried by air in Europe, this being necessary to maintain business in the articles in question. He is of the opinion that business cannot continue much longer to pay itself the advantages of aviation. The transcontinental service would not be abolished today. He referred to the airship as the most suitable medium for long flights like those across oceans.

Grover C. Loening mentioned successful flying that has been done for more than 3 years by individuals, the reason for this being the time saved. He said that 120 privately owned airplanes were flown to St. Louis from various parts of the Country at the time of the Air Meet there. He averred that there are not that many civilian airplanes in Europe. The St. Louis demonstration is an excellent example of what can be done after a proper start is made. Mr. Loening spoke of the limitations placed upon the dirigible by weather conditions but declared that the feasibility of traveling by airplane 120 m.p.h. for 1000 miles is a salable thing today.

R. B. C. Noorduyn, in mentioning the European subsidies, said that some of these are limited to two-thirds of the loss of operating companies and that some of the subsidy payments have resulted in good engineering development. He recommended that muffler experts devote their attention to aircraft, as the noise of aircraft causes some of the fear of them. With regard to staying in the air 20 hr. per day, the only thing that prevents this is the necessity of changing engines. He did not agree with Mr. Redden that organizations and not airplanes make air-lines. It is a matter of the craft to a large extent. Nothing but fog will stop the flight of an airplane today.

M. L. Paterson referred to ballooning done at night in 1835, and also to the extensive aircraft flying done during the war practically without lighting equipment. Mr. Paterson was associated with the company that was intimately connected with the development of the beacons that were used to light the route from Chicago to Cheyenne during the time of the Air Mail night flights. There are three classes of these beacons: 36-in. arc searchlight of 450,000,000 c.p., 18-in. incandescent and acetylene lights. There are, of course, various phases of illumination for night flying, including landing lights on planes and boundary lines for fields.

Chairman Cornelius T. Myers' conclusion, as a layman so far as aeronautics is concerned, was that in that art everyone is making progress and everyone is helping everyone else.

At the close of the meeting films were shown by the Aeromarine Company of flights of seaplanes and by the War Department of its latest dreadnaught bombing tests.

MANUFACTURING MORE QUIET GEARING

Detroit Section Production Meeting Produces Very Valuable Discussion

Gear noise and production methods for combating it were the topics discussed at the Detroit Section's first monthly production meeting on Nov. 15. This meeting can be recorded truthfully as one of the most interesting production sessions ever held by the Society. Over 200 were present and every man seemed to feel that he had profited greatly by his attendance. All of the talks were informal contributions to a scheduled round-table discussion of the question as to whether gears need to be ground to achieve reasonably quiet running. Representatives of the following companies spoke; Cadillac, Chandler, Lincoln, Packard, Reo and Studebaker. The more important points that were presented are recorded in the following report of the meeting. Because of their practical value, each of the informal discussions is to be printed in the form of a complete illustrated paper in a future issue of THE JOURNAL.

FUNDAMENTAL ANALYSIS OF GEAR NOISE

W. R. Griswold of the Packard engineering staff, opened the program with an interesting presentation of the elementary causes of gear noise. He called attention to the fact that two changed conditions are responsible for the present-day general complaints against gear noise; first, gear-ratios are much higher than in the past; second, a majority of the cars now being built are fitted with enclosed bodies.

If an alarm clock is allowed to ring inside a glass jar from which all air has been exhausted, its sound cannot be heard. Mr. Griswold cited this experiment to demonstrate that sound must pass through some medium to be heard. Vibration and wave motion are the source of all sound. Unfortunately, requirements of strength and durability force the use of the most resonant materials in transmission gears. Vibration is set up in these resonant metallic substances in three ways; first, by inaccuracies in the rolling surfaces of the teeth; second, by the elastic action of the gear teeth and the supporting shafts; and third, by the reversal in direction of the frictional forces as the gears rotate under load. Mr. Griswold called attention to the fact that the speed of sound is greatest through liquids and metallic solids, the two mediums of sound transmission present in all gear-boxes. He cited several interesting elementary physics experiments to illustrate the fundamental causes of noise.

METHODS OF ATTACKING THE NOISE PROBLEM

In conclusion, Mr. Griswold said that there were four ways of attacking the gear-noise problem

(1) Deliberate exhaustion of all experimental schemes, trying various modification of tooth form, pressure angle, pitch, material and bearings, until quiet is attained by a process of elimination

(2) Discovery of the causes by evolution or by accident, the least promising way, no doubt

(3) Determination of the causes and then controlling them at the source to prevent possibility of noise. This calls for extremely careful manufacturing and inspection

(4) Partially controlling the causes, and then applying corrective measures after the production of the parts, such as by grinding, burnishing, lapping or polishing

This presentation by Mr. Griswold of fundamentals served as an appropriate introduction to the talks that followed.

HOBBED AND OIL-TREATED GEARS MORE ACCURATE

Conclusions reached by the Studebaker manufacturing organization on the matter of attaining gear-accuracy were presented by O. H. Shaffer. Their studies of the gear problem have led them to favor cutting the gears more accurately by employing the hobbing process and then oil-treating them to avoid distortions in hardening. Curves were shown to illustrate the effect of carbonizing and hardening on an accurately cut tooth and to support the contention that hobbed teeth are more accurate than those which are milled or shaped. Both of the heat-treating operations tend to shorten the full depth of the green tooth, with a consequent deformation of its face due to the expansion of the thickness at the pitch circle. It is the opinion of the Studebaker men that gear grinding can be dispensed with if the teeth are cut with accurate hobs from a steel suitable for oil-treatment.

Cadillac Favorable to Gear-Grinding

L. A. Danse spoke for the manufacturing division of the Cadillac Motor Car Co. He said that their experience with the gear-grinding method had sold them completely on the advisability of grinding gear-teeth after hardening. He was most enthusiastic in his praise of the results achieved in the Cadillac plant saying that transmission tear-downs had been reduced from 30 per cent to less than 5 per cent of the daily production. Since these tear-downs cost in the neighborhood of $2.50 each, the saving is a material one and partly offsets the cost of the grinding operation. About 3 per cent of the old cut gears failed to pass inspection and had to be scrapped; grinding has reduced this loss to less than ⅛ of 1 per cent. Ground gears run so much more quietly than cut gears, that the Cadillac inspectors now complain about transmission bearing noises that were not noticeable before the introduction of the tooth-grinding process. Mr. Danse believes that the persistent campaign for quiet transmissions will lead to the development of transmission cases that will act as mufflers of the gear noises instead of tending to amplify them. He stated that Cadillac engineers are contemplating a change in the transmission to eliminate the so-called cluster gears on the countershaft, making them separate so that the teeth on all gears could be ground. This is indicative of their faith in the gear-grinding process as a noise deterrent.

Unquestionably, gear life is lengthened when the teeth are ground, Mr. Danse stated, but he was unable to quote any specific percentage, although this factor is under observation. He gave a very complete description of the gear-grinding machine used in the Cadillac works, but this will not be repeated here since it has been covered fully in The Journal[1].

Metallurgical Considerations

Gear-grinding was adopted in the Cadillac plant after a series of exhaustive experiments carried on over a period of years. Almost every conceivable kind of gear steel was tried in these experiments in an endeavor to overcome the warping of the teeth in the hardening process. Carbon-steels, nickel, chromium, vanadium and molybdenum alloy-steels were all tried in turn, but without appreciable success. These experiments led to the final adoption of S.A.E. Steel 3250, oil-treating stock, in all Cadillac transmission gears. Although many types of pots, compound and heating schemes had been tried, Mr. Danse said that he had been unable to carburize gears within 30 to 40 per cent of the accuracy obtainable with oil-treating methods. All manner of fixtures and clamps were used in trying to control distortion during the case-hardening process but without favorable result. All Cadillac transmission gears are now oil-treated; rear-axle gears have not been oil-treated as yet, but Mr. Danse believes that eventually this will be done with considerable success.

One of the most interesting contributions of the evening was Mr. Danse's comment on metal flow-lines in the forged gear-blank and their effect upon gear-tooth strength and gear distortion. At one time the Cadillac engineers conducted a series of impact tests on gear teeth to determine their ultimate strength. It was found that all teeth on the same gear did not have the same relative strength. Investigation showed that two of the teeth on a particular center-line had a maximum of strength and that those teeth on a center-line at right angles to this one of maximum strength showed a minimum of strength. After etching some gear blanks with acid to bring out any grain lines in the metal it was noticed that these lines passed through the blanks in the manner shown in the accompanying illustration. The teeth shown at *b*, having the flow lines passing through them longitudinally, proved to be the strongest teeth; the teeth shown at *a*, having the flow lines running across them, were the weakest teeth on the gear. Careful checking of results showed this condition to exist in all gears forged from the conventional steel billet.

[1] See Journal, June, 1923, p. 545.

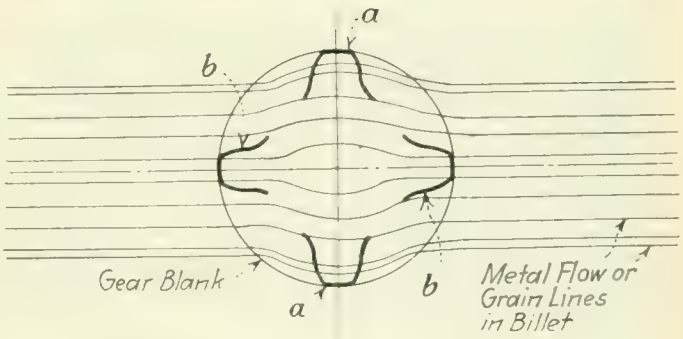


Diagram Showing the Relation between the Strong and the Relatively Weak Gear Teeth and the Grain Lines in the Billet

Upset Blanks Give Uniform Tooth-Strength

These tests demonstrated the desirability of using gear blanks in which the flow lines would radiate outward from the center of the blank. Experiments showed that blanks with this characteristic could be made by cutting circular discs from the end of round bar stock that had been subjected to an upsetting operation to produce the desired radial flow of the metal. Such upset blanks are now being used for Cadillac gear forgings.

Tests made on rear-axle bevel-gears showed that the weakest teeth on a gear cut from the forged blank withstood an impact of only 260 ft-lb; whereas, all teeth on a gear cut from one of the upset blanks withstood an impact of 1300 ft-lb. This is certainly an impressive increase in strength and can be attributed entirely to the fact that the metal flow-lines in the upset blank run radially through the teeth instead of running around the ring. This also has a marked effect upon the tendency to warp, the upset blank causing relatively little warping.

Lincoln Gears Burnished and Polished

R. E. Linn of the Lincoln production staff described methods of burnishing and polishing gear teeth that have proved effective in reducing gear noise. Burnishing is done by running the green gear in the middle of a group of three accurately cut and hardened gears whose centers are located on the vertices of a triangle. All three gears mesh with the gear being burnished. There should be a different number of teeth in the three hardened gears so that the effect of a hunting tooth is secured, thus preventing the meshing of the hardened teeth with the same spaces on the soft gear throughout the burnishing operations. This burnishing operation seems to roll or lay down the roughness of the tooth surface as left by the cutter and makes an appreciable improvement in the quietness of the gears. Each gear is burnished by rotating it for about 5 sec. in each direction.

Greater accuracy was attained in shaping Lincoln gear teeth by polishing the cutters used on the gear-shaping machines. A special polishing machine devised for this purpose is now used also for polishing the gears after the burnishing operation. This machine follows the generating principle of the gear-grinding machines now in general use but employs a rubber buffing wheel that is coated with tallow and emery-cake as an abrasive. About 3 or 4 min. is required to polish the average transmission gear on this machine. Ground gears can be polished by this method and the teeth given a mirror finish. Mr. Linn agreed that the grinding process was effective in correcting tooth-profile variations due to warpage in hardening.

Reo Has Rigid Cutter Inspection

Variations in gear teeth were traced by the Reo organization to inaccuracies in the cutters. W. G. Hildorf described a rigid system of cutter inspection used in the Reo works to assure new cutters being accurate and being kept so. All cutters are checked with a comparator and subjected to an additional test by inspecting two sample gears produced by each cutter, these gears being rolled together on a gear-

[illegible] and their action observed. All cutters are ground and recorded in a card file so that their periodic inspection can be maintained.

Bevel gears are cut from nickel forgings similar to those used by Cadillac, but S.A.E. Steel 3115 is used. The upsetting operation tends to minimize warping in the carburizing process. Mr. Hildreth said that observations made at the Bureau point to the conclusion that most warpage occurs in what is known as abnormal steel, that is, steel that does not carburize properly but tends to develop soft spots. He has used the Klingelnberg burnishing method satisfactorily, but some of the Bevel gears are now being ground, particularly those used in transmission-mounted in closed cars.

Burnishing Method Used by Chandler

A. H. Frauenthal, chief inspector of the Chandler Motor Car Co., wondered how far manufacturers could go in the way of expense to procure quiet gears and made the rather pertinent comment that each manufacturer is now scrambling to attain the same degree of gear-quietness as his competitor. The Chandler gears are made of chrome-carbon steel, oil-treated. He confirmed the Studebaker conclusion that oil-treating caused less tooth distortion than carburizing. Although all gears in the Chandler transmission are in constant mesh, a satisfactory degree of quiet is achieved by burnishing the teeth both before and after hardening. Gears are run for less than 5 sec. in the burnisher and only in one direction. Mr. Frauenthal said that gears could be spoiled easily by doing too much burnishing. He favored putting all back-lash in the larger gears since this affected the least alteration in the tooth contour.

December Meeting

The next production session of the Detroit Section will be held on the evening of Dec. 20 in the General Motors Building at 8 o'clock. Enameling of steel bodies with pyroxylin base materials will be the subject and will be treated from both the production and the engineering standpoints. The customary dinner at 6:30 p. m. will precede the meeting.

J. F. PALMER NOT WITH DUNLOP

Through a regrettable error in the story of the Buffalo Section's Oct. 29 meeting, on p. 429 of the November issue of THE JOURNAL, J. F. Palmer, who addressed the meeting, was reported as being connected with the Dunlop Tire & Rubber Co. Mr. Palmer is consulting engineer with the Hewitt Rubber Co. of Buffalo, and has no connection with Dunlop.

TO DISCUSS AUTOMOTIVE FUEL PROBLEM

American Petroleum Institute to Meet in St. Louis, Dec. 11 to 13

The American Petroleum Institute has issued the preliminary program for its fourth annual meeting to be held at the Hotel Statler, St. Louis, Dec. 11 to 13. Among the items of particular interest to the members of the Society are an all-day discussion of the automotive fuel problem on Dec. 12. At the morning session a paper on the Fuel Problem from the standpoint of the Automotive Industry will be presented and Dr. G. K. Burgess, director of the Bureau of Standards, will outline the progress made in the cooperative fuel tests as a paper entitled, What is Good Gasoline? At the afternoon session W. S. James, of the Bureau of Standards, will present a paper on Service Tests of Lubricants in Automotive Engines, and Thomas Midgley, Jr., vice-president of the General Motors Chemical Co., will speak on the Progress of Anti-Knock Fuels. At the general session on the evening of Dec. 12 three papers will be presented, one of which, entitled What the Automotive and Oil Industries Can Do for Each Other, will be by H. L. Horning, general manager and secretary of the Waukesha Motor Co., representing the Society of Automotive Engineers.

The annual dinner will be held on the evening of Dec. 13 at 8 o'clock in the ballroom. An invitation has been extended by the American Petroleum Institute to any members of the Society who care to attend the dinner. Persons desiring tickets should make reservations promptly through the office of the American Petroleum Institute, 17 West 44th Street, New York City, and a check in the amount of $6 for each place desired should accompany all requests for reservations. If more than one ticket is requested the name or names of all persons should be sent to avoid duplicating reservations and to insure proper seating arrangements.

MAINTENANCE BIG TRANSPORT PROBLEM

Mid-West Hears Beecroft Analyze Truck and Bus Situation at November Meeting

David Beecroft

In the motor transport field there exists, between the producer on the one hand and the consumer on the other, a set of relationships that of necessity must be carefully considered if the greatest measure of success is to come to both parties for a given expenditure of effort and money. It was with this thought in mind that David Beecroft, general manager of *Motor Transport*, prepared the paper on The Relation of the Automotive Manufacturer to Motor Transport which he presented at the Nov. 9 meeting of the Mid-West Section.

The motor truck and the motorbus are 100-per cent machines of industry. They are just as completely dollar-earners for their owners as the printing press is for the publisher, as the steam-shovel is for the building contractor or as the locomotive is for the railroads.

Former Relation of Maker to User Discussed

Two major causes contributed to the lack of as close relationship between the builder and the consumer as would have been desirable during the past 3 years. First, according to Mr. Beecroft, came the influence of the system of passenger-car sales through the distributor and dealer plan of organization. This plan was too literally followed by not a few motor-truck merchandising policies and it kept the builder and the consumer apart, except as the former found it necessary to send his special sales representatives to assist the dealer in carrying out the sale. Where branch house organization was relied upon, a much closer contact between the two parties resulted.

Secondly, came the lack of a keen realization that motor trucks can only be well sold if sold by virtue of their dollar-earning capacity. To these two reasons for lack of close relationship between the factory and the consumer might be added a third contributing factor, namely the influence of the war with its unexpected demand for vehicles due to the stimulation of industry and also to the assistance the railroads required during those years. A clear vision of how the builder and the consumer should travel side by side and step by step in shaping the motor-transport industry during these, its formative days, has been lacking.

Engineer Must be Future Link

In considering the part the engineer should play in this work of closer relationships he should be looked upon as the representative of the producer, as he has been responsible for the design of the vehicle that has been sold into the dollar-earning zone of the user. Alongside of the engineer must be

considered the sales organization that has been the one connecting link between the factory and the user.

The consumer is purchasing transportation today, rather than buying chassis specifications. As Mr. Beecroft pointed out, the truck user or fleet owner has a transportation problem. He formerly used the horse as the power generator, his animal locomotive, if the term may be used. He built his entire system of transportation around this animal. The boundaries of his business zone were determined by the mileage capacity of the animal; the shipping room facilities were planned in accordance with horse pace and capacity. The horse was the key. Then came the motor truck which was injected into this horse zone, into this system of transportation that was framed around the animal. It was but natural to use the motor-truck first as a substitute; but there was no reason why the engineer and the builder should not have gone into the field and studied at first-hand the transport needs of the user and scientifically applied the vehicle to the work. Work of this character was started in 1911, but it was done largely by the sales end, the sales engineering end as it was frequently called. Unfortunately this work was not so general as it should have been. It was unfortunate, too, that the engineer was not more generally injected into this work.

Maintenance an Engineering Problem

Mr. Beecroft presented as a major consideration to which the attention of engineers should be directed the thought that the present design of vehicle must be greatly modified to meet the change in times. As engineers the work lies ahead. The engineer must get the owner's viewpoint and design what might be termed a maintenance engine, as well as a power engine or a factory production engine. All engines must be repaired, must be overhauled, must be rebuilt. When laying out the engine on the drafting board, the engineer should have three standards of measure before him. He must design

(1) A power generator on a par with or better than his competitor
(2) A powerplant that permits of economic production
(3) A powerplant that permits of economical maintenance in the hands of the user

Of these three, the last gives evidence of primary importance, but all three units of measurement should be before the engineer in all of his work.

Fleet Owners Study Transportation Costs

When one considers that these vehicles are dollar earners and that they can only earn dollars when they are in working condition, it will be seen why the owner is considering the maintenance aspect. Every day the vehicle is out of service for repairs means a loss of revenue. Earning capacity is generally proportionate to the number of days the vehicle is in service from the time of its purchase until it is discarded. Realizing this, fleet owners are consulting together not only on matters of performance and maintenance but also with regard to future purchases.

Here is an example of how a medium-sized fleet owner is studying his transportation costs with the object of obtaining greater efficiency. He has brought together the average yearly index price figures of all materials that enter into the operation and maintenance of his vehicles from 1917 to 1922, inclusive, in order that his accountants can analyze the costs more specifically and place their fingers on the offending items. Other owners of small fleets are installing perpetual inventories in order that the amount of money tied up in spare parts can be reduced to the minimum.

Fleet owners who have used motor vehicles for many years are, in not a few instances, creating transportation departments for the complete control of the vehicles. Department stores have been leaders in this activity, but it is now being taken up in several other lines of industry.

From 8000 replies of fleet owners in all parts of the Country the numbers operating their own service-stations are as follows, these replies being classified according to the number of vehicles operated:

Number of Vehicles	Per Cent
10 or more	88.9
5 to 9	79.9
3 and 4	60.4
1 and 2	46.0

This great percentage of private service-stations has only one message; their owners have set their teeth to the work of reducing the actual cost of repairing and overhauling and they have also set their faces toward the reduction of the time a vehicle is out of commission during such work.

Commenting further on the figures given above, Mr. Beecroft explained that the result in the case of the owners of three or four vehicles was due to the fact that they were in relatively small places and owned relatively high-priced trucks. In some cases, such a fleet would be made up of three different makes of the highest-priced trucks on the market. It does seem unfortunate that in a small town an operator should load himself up with three different makes of vehicle and carry the maintenance load that goes with it.

Some of the reasons given by the operators of three and four-truck fleets for maintaining their own service-stations are given below, taken direct from the replies referred to. This group was chosen to represent the general situation, as what applies to the small fleet owner applies in still greater proportion to the large operator.

Schedule of Sections Meetings

DECEMBER

3—Buffalo Section—Automotive Electrical Equipment—William Knopp
4—New England Section—Drop Forgings as Applied to the Automotive Industry—John H. Nelson
Inspection of Wyman-Gordon Co. plant, Worcester, Mass.
5—Proposed Milwaukee Section—Observations on My European Trip—H. L. Horning
Minneapolis Section—Air-Cushioning of Automobiles—V. V. Vannattan
6—Detroit Section—Shock-Absorbers—J. M. McElroy
Indiana Section—Four-Wheel Brakes—Round Table Discussion
7—Washington Section—Experimental Aeronautical Development—Major L. MacDill
13—Metropolitan Section—Vehicles for Package Delivery—Round Table Discussion
14—Mid-West Section—What I Know About Engineering—Edward S. Jordan
20—Detroit Section—Enamelling of Steel Bodies with Duco—Round Table Discussion

(3) It is of as much importance to have our own
(4) We save
(5) We can watch our trucks better
(6) We can keep our vehicles in good operating con-
(7) More satisfactory work is done by our own repair
(8) The repair work is more accurate
(9) We get repairs made when we want them
(10) Cheaper in the long run and we have tried both
(11) Saves not only a great quantity of time but a vast amount of annoyance
(12) Our drivers take greater interest in our vehicles, knowing they are repaired by our own organization

What the future holds by way of possible equipment on motor trucks and buses can only be gaged by the dollar-earning value of these devices. There is only one reason that any equipment will live in the transport field and this is that it shows a profit when measured by the dollar-earning yardstick.

Mr. Beecroft cited the example of one builder of motor-buses who is meeting the new times that demand new measures and too often new men. This man had his engineer ride for weeks on certain bus lines to talk to the traveling public, without disclosing his identity, to get their point of view on the kind of buses they wanted. At the same time, a sales representative was taking the same course of training in another section of the Country, and in a third area, the bus driver was functioning similarly. The builder learned that the public wants to ride on rubber and to ride in comfort, and best of all, that it is willing to pay for such service. He learned that of two of his own buses operating on the same route, the greater earner was the vehicle that gave the comfort the public demanded and for which it was willing to pay the extra fare charged.

To sum up: Transportation is the business for which the vehicle was designed and the dollar-earning capacity of the vehicle, the yard-stick by which the user measures its success.

In the discussion which followed, W. Z. Pride of the Autocar Co. described in detail the development of cost accounting among fleet owners to lower maintenance costs.

H. L. Horning of the Waukesha Motor Co., pointed out that no great designer ever attains anything in design unless he translates his knowledge of design into things that will fit human nature. Any designer who thinks that his idea of a flange on paper or in steel is more important than the idea of the man who is using it, is making a purposeless design. Following this train of thought, Mr. Horning suggested possible improvements that might be made in the design of motor-truck electrical equipment, spark-plugs, push rods and carbureters. He also laid special stress on the need for improvement in the design of valves to facilitate quick removal and in the design of drivers' seats for greater comfort and a consequent increase in efficiency. Temperature and the composition of the lubricating oil as maintenance factors were also brought forward by Mr. Horning.

At the next meeting of the Mid-West Section, Edward S. Jordan, president of the Jordan Motor Car Co., will speak on What I Know About Engineering. The meeting will be held on Dec. 14 in the rooms of the Western Society of Engineers, 205 South Dearborn Street, Chicago. It will be preceded by an informal dinner at 6:30 p. m. in the Chicago Engineers' Club, 314 Federal Street.

NEW ENGLAND WILL MEET IN WORCESTER

Another combination of technical meeting and plant inspection has been planned for the meeting of the New England Section that is to be held on Dec. 4. Drop Forgings as Applied to the Automotive Industry will be the topic of the paper presented at the technical meeting at 8 o'clock in the Bancroft Hotel, Worcester, Mass. John H. Nelson, head of the experimental department of the Wyman-Gordon Co. of Worcester, will be the speaker. In the afternoon, members of the New England Section and their guests will be conducted through the Wyman-Gordon plant.

AUTOMOTIVE ELECTRICAL EQUIPMENT

For its meeting on Dec. 3, the Buffalo Section has scheduled a paper on Automotive Electrical Equipment by William Knopp, sales engineer of the Dayton Electrical Laboratories Co. The meeting will be held at the Statler Hotel, Buffalo, beginning promptly at 8 o'clock. There will be no dinner before the meeting this month.

REPAINTING AND REFINISHING

Processes for Bodies, Hoods, Fenders and Wheels Described by C. O. Thomae

Hoods, fenders and wheels must stand more wear and tear than automobile bodies, but less care is, as a rule, paid to the repainting and the refinishing of these parts. For this reason C. O. Thomae, technical representative of Valentine & Co., paid particular attention to their treatment, in his talk on Repainting and Refinishing of Automobile Bodies at the Nov. 2 meeting of the Washington Section.

To make the study of materials and methods more vivid to his hearers, Mr. Thomae suggested that they imagine themselves opening a paint shop to which cars are brought for refinishing. Five basic types of materials are required for a complete automobile painting system: Priming, surfacing, coloring, rubbing and finishing. Before any work is begun, the proper color must be selected. The owner should be consulted to make sure whether he wishes the car restored to its original color or to the darker tone it has reached in use. Such a consultation will save trouble later, and a complete record of the condition of the car when received in the shop as to dents, plating, interior upholstery, make of tires and similar information will also save complaints.

Preparing for the Color Coats

For removing the old paint, any of the paint and varnish removers on the market will do. It should be put on with an old brush, one coat after another, until it shrivels the paint, which can then be removed with a broad-bladed putty knife. The surface should be sandpapered smooth and great care should be taken to remove completely any rust spots, for rust will eat through any number of coats of paint. Mr. Thomae recommends deoxidine as a rust remover to be followed by careful washing with clear warm water.

Before applying the priming coat, the entire surface must be wiped off with a mixture of denatured alcohol and water to remove all grease and dirt. The priming coat, the foundation or anchor for the succeeding coats, should be spread on thin and brushed out evenly, as it will not stick if too heavy a coat is put on. It is important to adapt the primer to the surface treated. Lead colors can be used on wood, but they will corrode aluminum.

After the priming coat has had the proper time for drying, it is followed by what is called half-and-half, a mixture of equal parts of keg lead and roughstuff. Some painters sandpaper the priming coat, but Mr. Thomae objects to this practice because the sandpapered priming coat is easily cut through, especially at the edges. Sandpapering also removes the moisture-proof film. Another bad practice is glazing bodies with hard putty over the entire surface. This could be avoided by sending the body to the paint shop with fewer file marks and imperfections and a better paint job could be turned out.

Surfacing comes next. On high grade work, roughstuff is used and from three to five coats are applied according to the condition of the metal. Roughstuff is brought down to a smooth surface by using water and sandstone, followed by lump pumice to give it smoothness. The surfacer used on

rush work or work of cheaper grade is called sanding surfacer. As it is a shorter material, sandpaper can be used to give it a smooth surface; but if dry sandpaper were used on regular roughstuff, it would gum up on the paper. Great care must be taken to dry out all moisture after the roughstuff has been rubbed with sandstone and water. It should stand at least over night. The following day, No. 00 sandpaper should be used to clean out the corners and take off the sharp edges. The body is then ready for the ground color.

From Ground Color to Finish

The ground color should stand about 4 hr. before receiving what is called second coat color, which should also stand about 4 hr. The proper way to mix Japan color is to beat it up thoroughly with a wooden paddle and then add the turpentine gradually, stirring as the turpentine is added. This will produce a smooth color to work, but if the turpentine is poured in all at once, the color will have a sandy, gritty appearance.

The first coat of color and varnish should be applied in a room where the temperature is not below 70 deg. to give it freer working. The proportion of color to varnish should be about 2 to 4 lb. of paste color to 1 gal. of varnish, depending on the color used. In mixing color and varnish, apply the rule used for mixing the color. Beat up the Japan color with a paddle and add the varnish to it gradually. Care should be taken to have this first coat of color and varnish absolutely solid covering. The time allowed for drying will vary with the materials used.

Before the second coat is applied, it is usual to moss off the gloss and nibs or to remove them with wet sandpaper. Edges that have been cut or stripped should be carefully touched up. After an examination to make sure that the color is solid, any particles of grit that remain on the surface should be picked up with a tack rag, made as follows: Dip into rubbing varnish a piece of cheesecloth about the size of a large handkerchief, squeeze and spread out to dry until it becomes tacky.

In applying the second coat of color and varnish, use the proportions of the first coat of color and varnish and add to it about 50 per cent of rubbing varnish. In building up, the pigment should gradually be cut down. After the second coat has thoroughly dried, it should be rubbed with powdered pumice stone and water or with wet-or-dry sandpaper. Clean up with the tack rag before applying the third or tint coat. When this third coat has stood the required length of time, it should be rubbed with pumice stone and water and the necessary striping done. The next day the finishing coat can be applied.

There are two methods of preparing the body for the finishing coat. One is to rub slightly with rotten stone and water, wash clean, tack-rag and finish. The other is to use a mixture of a cup of gasoline in a pail of water and one or two spoonfuls of olive oil. With this mixture a piece of silk is used, squeezed out almost dry.

Before taking up the special problems of painting the hood, the fenders and the wheels, Mr. Thomae gave his audience some pointers on the color operation and sanding surfacer. Blue needs special treatment. If it is a medium or dark blue, a little varnish or linseed oil should be added to the color, and after standing about 4 hr. the blue color and varnish should be applied. If blue is allowed to stand too long, it gets so hard that when the color and varnish is applied it does not get a chance to feed on the hardened color and will not give a solid covering. After the third coat of color and varnish, the blue should be protected with a clear coat of rubbing varnish to help keep out the moisture.

The sanding surfacer should have what is called a sealer coat before the regular Japan color is applied, to add elasticity. Some painters make the mistake of trying to crowd the two operations into one by mixing a sealer with the color. The sealer is meant to go into the pores and penetrate the short material, but when the sealer is mixed with the color, it does not get a chance to do the work for which it is meant.

Painting the Hood, Fender and Wheels

The first step in painting the hood is to clean it thoroughly from all paint, grease and dirt before applying a coat of primer. If the metal is not smooth, apply one or two coats of sanding surfacer. When dry, sandpaper right down to the metal, leaving only the imperfections in the metal filled. After another coat of primer is brushed on thin, the operations outlined for painting the body can be followed with the exception of the finishing coat. This should be tougher varnish than the regular finishing varnishes used for the body, as the contraction and expansion are much greater on the hood.

The repainting of the fenders should be done in the same way, except that if the fender is to be black, a black primer should be used, followed by two coats of black color and varnish and finished with the tougher varnish used for the hood.

Disc wheels can be repainted by the method used for the hood, but fewer coats will be needed. On wooden wheels, after the paint has been removed and the surface thoroughly cleaned, a coat of primer should be applied, followed by putty glaze, if necessary. This should be sandpapered down absolutely smooth, before a second coat of primer is put on. The usual method of color, color and varnish, stripe and finish completes the job.

If a car is to be recolored, it should first be looked over very carefully for bruised spots. These should be patched with primer and filled up with glazing surfacer or roughstuff. When all grease has been removed with gasoline, the surface should be rubbed with pumice stone and water or wet-or-dry sandpaper. When the bare places or patched spots have been touched up, the regular routine of color and varnish and so on, as outlined for repainting the body, should be followed. If the color is to be changed, it will be necessary to apply a coat of flat color before the color and varnish is put on.

Asked about the refinishing of a car with a baked enamel surface, Mr. Thomae said that it is possible to refinish such a car without removing the enamel, but that because of the greasy or oily nature of the finish particular attention should be paid to the surfacing. Washing with benzol or alcohol should precede the priming coat.

One frequent cause of white spots on the cowl and the hood, according to Mr. Thomae, is the use of a strong blue or strong gray color varnish immediately under the finishing coat. Another is the use of too "short" or inelastic a finishing varnish, with a consequent spotting on the hood and the cowl which, because of their nearly flat position, are most directly attacked by the actinic rays in the sunlight.

An inelastic coat put on top of an elastic coat is responsible for the appearance of large cracks that show up beneath the surface like aligator skin, as a sample panel shown by Mr. Thomae demonstrated.

Major Leslie MacDill, of McCook Field, Dayton, Ohio, will give an illustrated talk on Experimental Aeronautical Development at the next meeting of the Washington Section, to be held in the lecture hall of the Cosmos Club on Dec. 7, at 8 o'clock.

MILWAUKEE TO HEAR H. L. HORNING

The Milwaukee group will vary its program of meetings on transportation problems at the December gathering when H. L. Horning, of the Waukesha Motor Co., will have for his topic Some Observations on My European Trip. The meeting will be held in Library Hall of the Milwaukee Public Library, Grand Avenue between Eighth and Ninth Streets, at 8 o'clock on Dec. 5.

AIR-CUSHIONING TOPIC AT MINNEAPOLIS

V. V. Vannattan is slated to present the much-discussed topic, Air-cushioning of Automobiles, at the Dec. 5 meeting of the Minneapolis Section. The meeting will be held, as usual, at 8 o'clock in the Manufacturers Club, Builders Exchange, Second Avenue, South, between Sixth and Seventh Streets.

PAIGE SPREADS HEAD-LAMP INFORMATION

The Detroit Section of the Society closed its Nov. 6 meeting with the Detroit Engineers Club. R. N. Paige, of the National Lamp Works of the General Electric Co., spoke on the Importance of Proper Automobile Head-Lamps and Proper Adjustment. This was substantially the same successful paper that Mr. Paige presented at the Summer Meeting and at a similar meeting of the Metropolitan Section's September meeting. The full text of the Summer Meeting paper was printed on pp. 35 to 39 of the July issue of THE JOURNAL. A summary of the points brought out in the discussion at the Metropolitan Section meeting and substantially all of the additional material that Mr. Paige presented at that time will be found on pp. 500 to 502 of the October issue of THE JOURNAL.

No meeting of the Dayton Section will be held in December.

SAN FRANCISCO MEMBERS MEET

Members of the Society living in San Francisco and its environs held a successful and well attended meeting on Nov. 21 at the Hotel Whitcomb in that city. W. S. Crowell gave an interesting talk on brakes and George G. Crackel of the Firestone Tire & Rubber Co. presented some of the advantages of low-pressure tires. These Pacific coast meetings are being arranged by A. A. MacCallum, who may be addressed at 115 New Montgomery Street, San Francisco, by any of the members who are interested.

PYROXYLIN-BASE PAINT MATERIALS

Dupont Engineer to Describe New Chemical and Methods of Using It

Duco, the new Dupont pyroxylin-base finish, will be thoroughly discussed, especially in relation to the enameling of steel bodies, at the monthly production meeting of the Detroit Section on Dec. 20. A Dupont engineer is expected to discuss the new finish from the technical and engineering standpoint, including a survey of the research and development work on it. Russel Rogers, of the Oakland Motor Car Co., will speak on Duco from the production standpoint.

The meeting will be held in the General Motors Building, Detroit. It will begin promptly at 8 o'clock on Dec. 20, after the customary dinner at 6:30 p. m.

THE ENGINEER AND THE USED CAR

Most Important of Dealers' Problems Discussed at Cleveland Section Meeting

In opening his talk on The Relation of the Engineer to the Used-Car Problem, at the Nov. 19 meeting of the Cleveland Section, David Beecroft, general manager of *Motor Transport*, laid stress on the fact that he was not offering any cure-all for the used-car situation, the greatest problem with which the industry is faced today.

It is almost an eternal question as to whom this problem really belongs. Mr. Beecroft quoted Edward S. Jordan, president of the Jordan Motor Car Co., to the effect that the greatest problem facing the automobile builder today is to find some way of protecting the public against the automobile dealer who sells that builder's product second hand without any definite policy on rebuilding, pricing, advertising and servicing.

Bankers Feel Seriousness of Situation

So important has this used-car problem become that a few months ago the Federal Reserve Bank of Chicago began taking note of it and so much concern is felt among Chicago dealers because of this latest factor injected into the problem. Each month the Federal Reserve Bank sends blanks to all Chicago dealers asking them these specific questions on their used-car business:

(1) How many used cars did you sell in October?
(2) How many used cars did you buy in October?
(3) How many used cars had you on hand Oct. 31?
(4) How many used cars did you buy in October, 1922?
(5) How many used cars did you sell in October, 1922?
(6) How many used cars had you on hand Oct. 31, 1922?

The reason for this latest attention of the Federal Reserve Bank is not difficult to find. The bank is looking for the protection of its member banks who are financing dealers, and the bank has become conscious of the fact that the ability of the dealer to sell new cars depends on his ability to dispose of the used cars he has on hand profitably, and also on the profits or losses he sustains on them.

No Profit in Used Car for Dealer

The very great increase in the sale of new cars during 1923, when estimates placed the number of new sales at approximately 3,800,000 vehicles, has resulted in more used cars being in the hands of dealers today than in any previous year at this season. It has been the pressure of the factories on the dealers to dispose of the greatly increased volume of new cars that has resulted in the loading up of the dealers with used cars. The trade-in percentage in new-car sales has increased this year, as compared with former years, and the dealer is confronted with a more serious used-car situation than ever before.

If the dealer could sell used cars so as to make money on them, there would be good business in selling used cars, but today the dealers lose money on the used cars, their profits are consumed and 30 per cent of them are forced out of business. The October bulletin of the National Automobile Dealers Association reported used-car losses at $5,654,000 lost by dealers for the 3 months ended Oct. 1. These dealers had 399,600 used cars on hand on Oct. 1, as compared with 430,000 on April 1. For the first 3 months of 1923, these dealers had on hand stocks of used cars that had cost them $152,000,000. They admitted that this figure was $23,000,000 above the market price of the cars, and later reports proven this estimate to be true. It is plain that these dealers pay too much for the used car and so cannot sell it at a high enough figure to make a profit.

The dealers are faced with the interesting fact that they are about the only merchants in the community whose merchandise returns to them after it has been sold, and they find that their major problem in business is not selling new automobiles, but in buying used vehicles once, twice and in some cases three times. This purchasing problem is the real crux of the used-car business. This is where the money is lost.

Why cannot the dealers sell the used cars at a profit? The first and a very important reason is that very often the dealer discovers that he cannot rebuild used cars as they should be rebuilt and then sell them for what they are really worth. The public lacks confidence in used cars that are not rebuilt, but sold on what is known as the "as is" basis, that is, sold just as purchased second hand from the consumer.

Why have so many dealers sold used cars on this unsatisfactory "as is" basis? Letters from representative dealers in all parts of the Country show that dealers doing business in districts where conditions differ and selling new cars that go into distinctly different fields, give very similar reasons for the present trouble. A summary of these letters makes it plain that the dealers feel that if the cars are originally built properly by the engineers, or by reason of their design, there is longer life in the cars, it costs less to overhaul them and the used cars will bring higher prices. There is evidently a very definite feeling that it lies within the province of the engineer to contribute materially to the solution of the used-car problem. It should further be kept in mind that the public feels there is a much closer relationship between the engineer and the used car problem than many engineers are conscious of.

Engineer Vitally Concerned in Used Car Problem

The engineer must stop designing cars for himself or as he is told to design them by the sales department. After all, it is the owner who sets the price on a used automobile.

For example, the excessive amount of time required to handle the electrical unit has become very generally known among owners and undoubtedly has resulted in a reduction in the sale of the new car of that make, as well as in the market value of the car as a second-hand product, according to a member of the Society in charge of one of the largest electric service organizations in the Country.

On this point, Mr. Beecroft quoted a large dealer who has been selling a high-priced automobile for the past 20 years. This dealer maintains that there is no question but that the lack of accessibility has been a serious handicap in the sale of used cars. He has found it very difficult to sell a thoroughly rebuilt car and make money on the resale, because the cost of rebuilding is so high, because of the design or lack of design and also because of the cost of spares. It is not good business to sell second-hand cars in "as is" condition, but it is too often necessary to do so.

As to the desirability of rebuilding the second-hand car before selling it, rather than disposing of it in the "as is" condition, Mr. Beecroft believes there is little ground for dispute, even when the low-priced cars are considered. One dealer reports that the used car, when reconditioned and repainted, even in the under $1,000 field, finds a ready sale at a more substantial price, which thus helps to standardize car values. The engineer's relation to the used-car problem plays a very strong part, as beyond a question, a used car has considerably more value when its mechanical condition is good. Another point where the engineer plays a part is in the supplying of mechanical units so that their replacement will be comparatively easy when a car is being reconditioned for resale.

Nevertheless, according to one dealer handling a car listed at under $1,000, it is not expected that the improved designing or engineering of a motor car will entirely eliminate the used-car burden from the trade, because many people like to change cars every year or so, even though the present car is running well, just to secure the most recent change in lines or finish.

Still another dealer quoted by Mr. Beecroft believes that the mechanical or engineering department of an automobile dealer must decide how much should be spent upon used cars before they are offered for resale. That is where the engineer comes in, and it would tie the factory up much closer to the owner if it were incumbent upon the engineering department of the factory to give advice and pass on the rebuilding work.

Mr. Beecroft put the question up to the engineer by asking whether automotive engineers have not given more thought to obtaining a certain result in the way of performance than they have to the ultimate cost of operation. The owner gets his first impression of the engineering that has gone into his car from the amount of the repair bills. The work of the engineer is measured by the years of service in the vehicle, and the older the car becomes, the more apparent and conspicuous becomes the work of the engineer. If the work of the engineer is poor, production, merchandising and servicing, all dependent on design, come tumbling down like a house of cards.

In the discussion that followed Mr. Beecroft's paper, John Younger, chairman of the Cleveland Section, commented on the tremendous waste involved in scrapping worn-out automobiles. One and a half million cars will be sent to the scrap heap this year, and averaging 2000 lb. for each car, at about $0.35 per lb., the sum involved is large enough to be considered seriously. Between 25 and 50 little parts wear and cause a used car to be scrapped. If the engineer made those parts slightly bigger or heavier or put better metal into them, they would not give trouble.

If a car has been used for some time, only one thing can be done; have it overhauled completely. Whether the car is accessible or inaccessible does not make much difference, it should be torn down, every piece scrutinized and inspected and then rebuilt. It is surprising how much stuff can be used, avoiding waste and reclaiming some of the huge quantity of material now thrown away.

It is the opinion of Mr. Buckman, manager of the Cleveland Automobile Dealers & Manufacturers Association that the used car can be, and should be, made an asset in the dealer's business. The greatest asset that the automobile industry has in the moving of new cars is the used cars now in the hands of the American public. In other words, when a man has a used car, he has the first payment on a new one. He has not only the desire to own another car, but he has a big step in the payment for that car. It remains a question, therefore, whether the used car should be traded on that basis or whether it will be made a bunch of junk. An automobile is transportation; it is so much mileage. Even if the car is traded in, there is still mileage left in it. The next thing to do is to convince the public of this. No one dealer or builder can do that alone. The dealers must get together to bring the used car up to a definite standard and then impress that standard on the public with the assurance that it is being lived up to. Mr. Buckman explained that it is just that which the Automobile Dealers & Manufacturers Association is trying to do in Cleveland. The used-car bureau of the Association inspects the cars and places the seal of the Association on them to testify that they are worth the money asked. This is a constructive effort to make the used car an asset, instead of a liability, as it now is. Advertising seems to be the way to establish the true worth of the used car in the minds of the public.

MEASURING RIDING QUALITY

Indiana Section Hears T. J. Litle, Jr., Describe Ingenious Testing Methods

T. J. Litle, Jr.

Unique methods of studying engine and chassis vibration and riding quality were revealed to the members of the Indiana Section at their November meeting, which was attended by more than 150 men. T. J. Litle, Jr., chief engineer of the Lincoln Division of the Ford Motor Co., read a most interesting paper setting forth some novel experiments he has made in an effort to locate and eliminate disagreeable vibrations. He also described a mechanism for recording relative body and axle movement of a car when in operation. Mr. Litle's complete illustrated paper will be found in this issue of THE JOURNAL, starting on page 445. Some of the points raised in the discussion of the paper are reported in the following paragraphs. Asked whether he thought balloon tires would ever be developed to a point where they might replace chassis springs entirely, Mr. Litle replied that he did not. They improve the riding quality of a car without any question, but it is best to secure the full value of the combination of low-pressure tires and springs, neither being wholly adequate alone. It has been his experience that some type of shock-absorber is necessary with low-pressure tire equipment. This is particularly true of the front of the car. This experience of Mr. Litle checks with that of other engineers who have experimented with low-pressure tires.

Shock-Absorbers Should Have Neutral Zone

From rather comprehensive tests, Mr. Litle has concluded that hydraulic shock-absorbers are very effective in improving riding qualities. He spoke particularly of a type developed at the suggestion of his company which is arranged with a neutral zone for slight movements of the spring so that the shock-absorber is actually inoperative on rela-

[illegible] smooth roads. Without this neutral arrangement, the [illegible] shock absorber restrained the spring action so that the value of using a softer chassis spring was apparent. [illegible] should be inoperative on smooth roads. [illegible] spring leaves is favored by Mr. Litle. [illegible] referred to the use of spring covers as a means of [illegible] dirt and water from between the leaves.

H. Hunt, of the General Motors Research Corporation, wondered whether the comfort of the car-rider was not more [illegible] represented by records of acceleration and deceleration of the car seat. Mr. Litle agreed that it was, but said the device described in his paper had enabled him to make a productive study of different combinations of [illegible] of varying length and thickness. He recalled a method described some years ago before a meeting of the S[illegible] where a photographic record was made of the movements of lights attached to the passengers, chassis and body, as the car was driven over an obstruction.[1]

W. G. Wall suggested that perfectly definite measurements of axle and body movements could be taken if it were possible to mount the instrument on a horizontal reference [illegible] in the air. This suggested the possibility of mounting a seismograph on a trolley wire above the road. He also spoke briefly on the problem of synchronizing or harmonizing the front and rear springs and agreed with Mr. Litle that a neutral zone is desirable in shock-absorber action.

Balloon Tires Interfere With Wheel-Housings

One difficulty met with balloon tires by Mr. Litle was their interference with body wheel-housings when standard wheel-tread and rear-seat widths are used. Edward Schipper said that some cars were using a 60-in. tread when low-pressure tires were fitted to avoid this interference.

Asked whether he had tested cars with the front-axle location in varying fore-and-aft positions on the spring, Mr. Litle replied that he had, and that his tests substantiated the general practice of having the axle located well forward of the spring center. One objection that he has found with low-pressure tires is their tendency to set-up violent front-wheel shimmy, particularly at high speeds.

Four-Wheel Brakes to Be December Topic

The Indiana Section's next meeting will be held on the [illegible] of Dec. 6 in the Hotel Severin, Indianapolis. The topic will be Four-Wheel Brakes.

ACCURATE BRAKE PERFORMANCE TESTS

W. S. James Describes Bureau of Standards Recording Decelerometer and Results

W. S. James

An extremely interesting analysis of motor-car brake fundamentals was presented at the November meeting of the New England Section by W. S. James of the Bureau of Standards staff. It was evident to all present that the Bureau is starting its study of braking from rock-bottom and that this method of attack is uncovering the basic principles of decelerating motor cars. Mr. James gave some very convincing demonstrations of brake action with a miniature automobile fitted with electrically-controlled brakes on four wheels. He also exhibited and explained the operation of the Bureau of Standards recording decelerometer that has made it possible for the Bureau engineers to analyze brake performance more accurately than has been possible with the measured stop-tests universally used in the past by other experimenters. This very valuable device is described fully on p. 499 of this issue of The Journal.

No attempt will be made in this brief report to present an abstract of Mr. James remarks since they are to be the basis of a very comprehensive paper that he will present at the Annual Meeting in Detroit next month. However, it will be of interest to record a few of the conclusions drawn from the tests and observations that have been made with the Bureau of Standards decelerometer and the other brake studies made by the Bureau engineers.

After spending some little time on elementary mathematical analyses of the forces acting on a car during deceleration, Mr. James emphasized the following fundamental facts:

(1) The retarding force acting on the car is proportional to the change in speed per unit of time, regardless of what units of speed and time are used

(2) The distance within which the car is brought to rest is directly proportional to the square of the velocity from which it is stopped, and inversely proportional to the deceleration in feet per second per second

Although the stopping distance varies largely with a change in the speed of the car, the deceleration in feet per second per second or the resisting force per pound of car weight is practically independent of the car speed. This latter fact has made the study of brake performance relatively simple.

Lacking reliable data on the coefficients of friction between the tire and the road, the Bureau of Standards made some rather crude but enlightening tests by towing a section of an automobile tire, weighted with a uniform load of 50 lb., over various types of surface and measuring its resistance to motion with a spring balance. The highest coefficient of friction observed in these tests was between dry glass and a tire tread of a rather poor grade of rubber. The samples were pulled with the tread both parallel with and crossways to the direction of pull so that coefficients were observed for a straight-ahead slip and for a slip sideways. Note was made of the pull at which sliding started and that necessary to maintain sliding at a relatively slow speed. Mr. James emphasized that the numerical data obtained were not to be taken as applicable directly to cars on the road but rather as indicative of some of the relations that may hold in ordinary braking service. It was observed that more pull was required to maintain sliding of the tire than that required to start it. If this result is substantiated by later experiments, it may disprove the present general conception that the coefficient of friction drops when the tire starts to skid on the road. Another interesting observation was that the resistance to sliding in a sideways direction was almost the same as that in a fore-and-aft direction.

Coefficient of Wet Concrete Higher Than Dry

One surprising result of these tests was the difference in the coefficient of friction between hard-surfaced pavement when wet and when dry. Tests made in water puddles on a concrete road indicated that the coefficient of friction was higher in the puddle than on the dry road. Mr. James attributed this to the presence of dust and dirt on the dry pavement which acted as a sort of ball-bearing support to let the tire slide easily. This was not present in the case of the wet concrete and the coefficient increased as a result. With the maximum coefficient of friction found between tires and roads of different types, the maximum deceleration attainable lies in the neighborhood of 23 ft. per sec. per sec. All of the tests on hard surfaces showed that the pull on the tire was practically independent of the tire-tread configuration, but was influenced by the character of the tread rubber. Soft rubber had a higher coefficient of friction, hard rubber a lower one.

Mr. James gave a brief mathematical analysis of the

[1] See Trans. Vol. 22, pt. 2, p. 462

forces and reactions that act on a car to produce skidding. This led him to mention the importance of the relation between side resistance and straight-ahead resistance in tires now that higher deceleration is possible with four-wheel brakes. If a car should be turning on a 30-ft. radius at 20 m.p.h. it will have a force acting to slide it sideways equivalent to 1 lb. per lb. of car weight and it will become very difficult to overcome that force with the side resistance of the ordinary tire. This emphasizes the importance of banking curves on new highways with the advent of higher decelerations. Mr. James remarked that if we are to use brakes that stop a car quickly, we must also stop the car safely, and that calls for some discretion on the part of the driver. We must become educated to use decelerating forces that are capable of imposing a 2000-lb. load on a 3000-lb. car when it is being decelerated at 20 ft. per sec. per sec.

A large number of representative records taken with the Bureau of Standards decelerometer were shown to the audience in slide form. From these Mr. James indicated several interesting points. He showed that the name "emergency-brake" is certainly a misnomer for the average hand-brake, since it seldom exceeds a deceleration of 8 ft. per sec. per sec., whereas the foot-brake comes nearer 13 ft. per sec. per sec.

Why Balloon Tires Improve Braking

What may prove to be the explanation of the improved braking performance of cars fitted with low-pressure tires was found in studying the decelerometer records from one series of tests made by Mr. James. Four records were taken on the same car, the tire inflation-pressures being different in each case, varying from 70 to 25 lb. per sq. in. The car was driven over smooth asphalt pavement and stopped from a speed of 35 m.p.h. In the case of the tire inflated at low pressure, the decelerometer record is a fairly straight line, showing that the rear wheels held the ground and the decelerating force was acting all of the time. In the case of the higher pressures, the line on the record was decidedly irregular, showing that the rear axle was bouncing or vibrating on the road, the brakes not being wholly effective until the car speed had been materially reduced.

Another interesting point shown by the performance tests was the drop in braking efficiency when the brake-drums and linings become hot. In one case this change in conditions caused a drop in deceleration from 11.5 to 9 ft. per sec. per sec., the latter figure being for the hot brakes.

Rather active discussion was held after Mr. James concluded his remarks and the meeting did not adjourn until a late hour. The attendance reached nearly 100 persons and all joined in voting the meeting one of the most interesting ever held by the New England Section.

DAYTON SERVICE MEETING

Important Discussion Favorably Received by Service Men and Engineers

The most constructive national meeting ever held for the purpose of promoting more adequate and satisfactory automotive service was that conducted in Dayton, Nov. 20 and 21, under the joint auspices of the National Automobile Chamber of Commerce and the Society. About 200 men interested in service and engineering were present. They came from all sections of the Country; nearly every motor-car builder was represented. The sessions were well attended and the numerous talks enthusiastically received. Quoting one prominent service manager, "the Dayton meeting was a humdinger."

This was the first joint gathering of the N. A. C. C. and the S. A. E. on service matters. Without any question, the plan of combining forces increased the attendance, the interest and the effectiveness of the meeting; there is little doubt that the Society is favorable to the holding of such joint meetings annually.

A complete illustrated report of what transpired at the Dayton meeting is set forth in the following columns. C. F. Kettering's introductory talk was a distinct hit. The papers on head-lamp adjustment, lessons from the flat-rate, dilution, electrical repairs and simplicity of repair tools contained many valuable suggestions. W. T. Kreusser's analysis of service repairs for the use of car designers gave every man present plenty to think about.

Excursions were made to McCook Field, the Delco and the National Cash Register Co. plants, and to the laboratories of the General Motors Research Corporation. A large number of those in attendance made these visits. Congratulations are extended to the Service Committee of the National Automobile Chamber of Commerce, the local committees in Dayton and the several speakers, on the unqualified success of this important gathering for the promotion of better automotive service.

KETTERING ANALYZES SERVICE EVILS

Trained Rural Mechanics, Lower Repair-Part Costs and Correlated Effort Needed

C. F. Kettering

C. F. Kettering made some frank but decidedly constructive comments on automobile service in the opening address of the meeting. One thing is certain; he dispelled any optimistic feeling that service as rendered today represents the public's conception of what real service should be. The talk was given in Mr. Kettering's characteristic vein of humor, each point being illustrated by examples of his and other motorists' experiences. He emphasized three major points as important in the campaign for better service: first, a closer correlation of the engineering, sales and service departments; second, reduction of repair-parts costs; third, educational work directed at the small-town garageman.

It is extremely important that the automobile engineer's office be located adjacent to those of the service manager and the cost accountant, in Mr. Kettering's opinion. In a great many cases, cars have been designed with production and sales costs solely in mind; service requirements have been slighted in the struggle for lowered production costs. In the future, this attitude can not be tolerated. Mr. Kettering urged those present to return to their factories with a determination to convince their superiors that a closer correlation must be effected between the sales, engineering and service activities of their companies. Recognition must be taken of the fact that the primary function of service is to contribute something toward more satisfactory operation of the car in the owner's hands and the provision of transportation at a minimum of cost to him.

Designers Must Recognize Service Requirements

Many of Mr. Kettering's remarks were directed at the car designer. He said that designs which made it necessary to lift the body to remove the generator, or necessitated removal of the radiator to fit a new fan-belt, were inexcusable and would not be accepted by the public in the future. Analyzing the cost of operating a passenger car, he emphasized the relative importance of depreciation and maintenance expense as opposed to fuel cost. Engineers might better concentrate on lowering the first-mentioned items than devote too much thought to fine carbureter adjustments to effect an increase in the fuel economy of 10 per cent. Suggestions received from dealers and repairmen should not be ridiculed by the engineer. Although such reports are at great variance in most instances, it must be remembered that engineers find it difficult to agree on a solution of some problems. Tests made by garage-men are usually

Causes of Trouble Not Properly Diagnosed

To appreciate the present-day status of automotive service, one must drive from New York City to San Francisco depending upon the small-town garage for repairs and adjustments. Most of the local mechanics know relatively little about diagnosing the real trouble with a car. Mr. Kettering cited many experiences to indicate how major parts are replaced, engines torn-down, valves ground and special accessories fitted to correct simple faults in operation due to lose terminals, leaky vacuum-tank fittings and similar minor causes. These things are happening in the small centers, not in the large metropolitan service plants. Investigations have revealed the astounding fact that 25 per cent of the cars in the United States are repaired in garages that have dirt floors. This gives some conception of the amount of repair work that must be done in a primitive fashion. Most car-owners know little or nothing about the mechanism of their cars and show no inclination to learn. They depend entirely on the judgment of untrained, uninformed small-town repairmen. Undoubtedly the most general complaint heard from the average owner is that "they had the car three days, charged me $45 and *they did not fix it.*" Mr. Kettering believed that one of the most crying needs of service today is for more trained diagnosticians who can put their fingers on the real source of engine or chassis trouble and suggest the simplest means of correcting it.

These conditions show the need for an educational movement to carry reliable and authoritative information to the small-town repairman. Mr. Kettering warned that this would be a long process and that trained mechanics could not be produced by the waving of any magic wand. The industry has been so busy with matters of great urgency during its development stage that comparatively little concerted effort has been put forth to educate mechanics in the towns and villages. However, these men are conscientious and eager to learn. Unfortunately, they have been getting and accepting unreliable advice and information from traveling accessory-salesmen who have been the only representatives of the industry who had direct contact with them in past years. Mr. Kettering said that he had observed on the shelves of small-town garages stocks of spark-plugs, primers, lubricators, carbureting devices, batteries and so-called improvement-fittings, of makes and designs unheard of in standard production. Accepting the salesman's claims as gospel, the garageman attempts to remedy minor engine ailments by selling these devices and parts to the car-owner at every opportunity. This propaganda of the traveling salesman, who always has a device vastly superior to that fitted on the car as standard equipment, must be combated by concerted and persistent educational campaigns that will place sound, reliable and authoritative information in the hands of the small-town repairman in a form that he can understand and use in his daily work.

Sales Competition Will Raise Service Standards

Mr. Kettering predicted that keen competition for new car sales will have a beneficial effect on service in the next couple of years. Manufacturers will be more receptive to suggestions that are made in the interest of better service. The movement of used cars will be influenced by the character of service rendered by their builders and this will control the sale of new cars to a large extent. Exorbitant cost of repair parts is one of the serious complaints made against present-day service. Mr. Kettering said that keen sales competition will convince the factories that service means more than the sale of repair parts. He emphasized the fact that the high price of small parts, subjected to excessive wear and frequent replacement, is the source of greatest complaint and needs attention first.

N. A. C. C. SERVICE DIVISION PLATFORM

Plan for Future Meetings and Educational Work Approved at the Dayton Meeting

The functions of the Service Division of the National Automobile Chamber of Commerce and some of its definite aims for the near future were set forth in the form of a platform at the Dayton Service Meeting. Some of the more important projects described in the platform are worthy of mention.

The regular November meetings are to be joint meetings with the Society of Automotive Engineers. The November meeting for 1924 will deal with service-engineering topics of interest to sales managers; that of 1925 to production managers, and they will be invited to the meetings. The May meetings, beginning with the one next May, will hereafter be national service congresses, to which will be invited all people interested in service, including, besides factory service folk, representatives of dealers, garages, independent repair-shops, equipment manufacturers, dealer and service associations, automobile schools, trade papers and the public. These meetings will be devoted to talks by prominent men engaged in the various fields of service operation. The object of a national gathering of everyone connected with the servicing of motor cars is to promote unity of thought and action and to build up in the minds of all those engaged the true conception of service and their responsibility to it.

Equipment manufacturers will be invited to exhibit time-saving and garage tools at these congresses, so that dealers and service-station representatives can examine and become familiar with the various tools offered for sale.

As opportunity offers, the scope and usefulness of the *Service Bulletin* of the National Automobile Chamber of Commerce will be extended, giving it wider distribution. It will be sent to every member of every service association. Effort to educate those who perform service in the field has been made not only in the two ways already mentioned, certain of their representatives being invited to the semi-annual meetings and some being placed on the *Service Bulletin* mailing list, but principally by promoting the establishment and conduct of local service associations in the different cities.

Establishment of Service Associations

This movement has met with some success but in proportion to its merit is far from amounting to what it should and the Division intends to encourage the new and stimulate the old service-associations to renewed activity. To this end it will be necessary to send speakers to address them, this being arranged through a Service Speakers Bureau. There is also in process of compilation a Service Association Manual.

A school for dealers and service associations is contemplated by the National Automobile Chamber of Commerce in cooperation with the National Automobile Dealers Association. This would be an annual affair, lasting 2 weeks. Educational matter is to be circulated among the motoring public through motorists' publications, automobile sections of daily papers and radio broadcasting. This is intended to instruct motorists in the care of their cars.

Men who entered the service field before automobile service schools or courses were available had to learn from the school of experience. It is believed that much can be done for those who have passed the school age and are already

SERVICE COMMITTEE OF THE NATIONAL AUTOMOBILE CHAMBER OF COMMERCE

engaged in service and for those who will enter it without a school course, by laying-out a course of reading graded according to the previous knowledge of the student but calculated to fit both those entering at the lowest rungs and those who have advanced farther up the ladder. Work has been begun on this course by the Division.

DIRT, NOT DILUTION, SCORED

How Excessive Dilution and Sludging of Crankcase Oil Can Be Eliminated

Dilution and sludging of crankcase oil are undoubtedly among the most important phases of the lubrication problem. However, E. F. Hallock, manager of the manufacturers' service division of the Vacuum Oil Co., minimized the *direct* evils of dilution in itself, in his address on The Evils of Crankcase Dilution; How To Educate the Public, and stated that satisfactory lubrication of internal-combustion engines can be maintained with highly diluted oil provided the lubricant be kept free from dirt and other foreign material. He felt that steps should be taken to educate the public in regard to dilution and sludging and suggested that the oil industry would accept gladly its part of the joint responsibility of accomplishing this task.

In connection with the problem of dilution, Mr. Hallock stated that since 1910 the end-point of gasoline sold commercially has been raised from 320 to 438 deg. fahr., this causing greater dilution at present than has ever before prevailed. Among other causes for dilution he mentioned poor mechanical condition of the engine, poor ignition, incorrect timing, improper carbureter adjustment and excessive use of the choke.

Supporting his contention that dilution is only indirectly responsible for lubrication difficulties, the speaker cited the satisfactory use of a mixture of 1 part of cylinder oil to 40 parts of gasoline in two-stroke-cycle marine engines, and a mixture of one in eight in high-speed, air-cooled, two-stroke-cycle engines. He stated that any increased wear resulting from the use of thinned oil is caused directly by the presence of dirt and other foreign matter capable of breaking through the thin-oil film to cause abrasion. Tests were mentioned to show that it is possible to run an engine with diluted oil if the oil be kept clean. With a view to correcting lubrication troubles, frequent drainage was advocated, not because of dilution but because of contamination.

The speaker decried the use of heavy-body oils to solve the dilution problem and claimed that such practice is bound to cause gumming and excessive carbon formation without affecting a cure. Instructions on how to avoid crankcase dilution included the following:

(1) Avoid excessive use of choke
(2) Use radiator cover
(3) Avoid idling for long periods
(4) Keep engine in good mechanical condition
(5) Drain oil-pan every 1000 miles in summer and every 500 miles in winter
(6) Do not flush crankcase with kerosene. Drain crankcase while engine is warm and oil agitated; this will carry off sediment

Emulsification or sludging and corrosion were also discussed at some length. The presence of dirt and water caused by condenser action of the crankcase were given as chief causes for the sludging. Cars used for short runs in city driving were said to suffer most from this trouble. The following items were included in suggested instructions on how to avoid sludging:

(1) Take frequent samples of crankcase oil to detect presence of water in excess
(2) Use suitable radiator-cover
(3) Clean oil-screen after every 100 hr. of service
(4) Select proper fuel. High-test gasoline gives better service
(5) Renew oil frequently and, if sludging has occurred, drop the oil-pan and clean it thoroughly

Mr. Hallock discussed at some length the causes for carbon deposit and acid corrosion. He also suggested means for avoiding excessive trouble from these causes. In conclusion he treated the subject of oil-pumping and gave the following instructions for avoiding oil-pumping and carbon deposit:

(1) Use highest-quality oil
(2) Fill crankcase to proper level daily
(3) Keep engine in good mechanical condition. Do not attempt to rectify mechanical faults by the use of heavier-body oils
(4) Do not try to get higher indications on the oil pressure-gage by adjusting the relief-valve
(5) Be sure that shims are properly fitted to crank-pin
(6) Adjust carbureter properly
(7) Eliminate "missing"
(8) Keep valves properly ground, tappets properly adjusted, and pet-cocks and gaskets tight

FORD SERVICE PRACTICE

Necessity for Standardization of Design and Manufacture Emphasized

Speaking on the subject, What Part the Engineer Can Play in Reducing Repair Costs by Eliminating the Need for Costly Tools, W. A. Francis, manager of the Ford Motor Co. of Cincinnati, brought to bear his experience of a long term of years. He premised his remarks by saying that costly tools will not be eliminated so far as their own price is concerned, the object to be attained being, of course, the reduction of service costs in view of the volume of work to be done. He stressed the importance of simplicity of car construction and of accessibility of all working parts. Yearly changes of models make for incomplete service equipment and result in costly repairs or the installation of expensive tools, placing a burden on the dealers as well as on the users concerned. Standardization looking toward simplicity makes for completely equipped repair-shops, installation of speed tools and the development of highly efficient mechanical ability of the personnel, all this resulting in the reduction of repair cost to the minimum. Complexity of construction means difficulty in locating trouble as well as additional difficulty in eliminating it. Mr. Francis said that Ford dealers could not carry complete stocks of parts if the policy of standardized manufacture were not adhered to. Not many years ago repair-shops in general were poorly equipped, with hand-tools and occasionally with upright drilling machines, emery wheels and the like. The Ford Company has over 9000 sales dealers and their investment in parts amounts to over $50,000,000. Throughout the world, there are 33,000 authorized sales dealers and authorized service dealers. The investigation made several years ago

[illegible] that the average shop for Ford cars could be equipped for [illegible]. The cost of repairs is, of course, reduced by low prices for [illegible] parts. It is evident that the qualities of [illegible] and economy are uppermost in the mind of car-owners. They expect efficient service from good local shops.

The price of Ford cars is 20 per cent less than it was in 1914, while [illegible] have the items of labor and clerical force [illegible] 100 per cent.

Every department of the dealer's establishment must function properly and profitably, especially the service department. Large-volume production has resulted in an unparalleled reduction in prices and lower commissions per unit with an increasing number of "trade-ins." Drastic changes in car models impose a higher rate of depreciation of the [illegible] value of automobiles than has occurred in any other line of manufacture; some models have become obsolete from the sales standpoint in less than a year's time.

Mr. Francis drove home emphatically his point that the engineer can play an important part in the reduction of repair costs by eliminating the need for unduly costly tools, the method for doing this being the standardization of all moving parts of motor vehicles.

In the discussion, A. B. Cumner, vice-president of the Autocar Co., said that the tool question cannot be eliminated. He believes that the tools need not be costly and that the engineers are not familiar enough with the tools that are available in the open market for shop equipment, this being evidenced by the fact that, in the design of parts, in many cases holes and lugs have not been provided for the proper use of these tools. He said that, in his opinion, in general procedure efficient repair-shop tools cannot be developed at the factory as the men there are fully occupied on production problems. Many valuable tools have been developed in the field, discarded vehicle parts being utilized in this connection. Mr. Cumner advised strongly that when any change is made on a car, it should be applicable to the prior models. Tool cost can be kept lower in this way. F. A. Bonham, the chairman of the meeting, entered a plea for adequate accessibility of all elements of assemblies that must be reached in repair work. He spoke of one design that required 21 special wrenches.

THE AUTOMOBILE HEAD-LAMP SITUATION

Suggestions for Improvement Are Given by Bureau of Standards

E. E. Carlson, mechanical engineer of the Bureau of Standards, analyzed the head-lamp glare situation before the Dayton Service Meeting. He gave a general picture of present conditions, embracing the work of the Society and the Illuminating Engineering Society, the trend of legislation and activities of State motor vehicle officials. He also outlined an educational campaign needed to improve conditions and gave an interesting demonstration of a simple method of adjusting head-lamps. He said in part:

Most automobile head-lamps do not give good road illumination because the owner does not know what constitutes a good road illumination or does not have sufficient interest in the subject to have the lights adjusted, or, with the equipment on the car, good light is impossible of attainment. Better head-lamp equipment is being furnished with the newer cars but the millions of older cars in use must be considered. The reflectors are often dirty, tarnished or rusted, the focusing device is cumbersome to operate, may not allow focusing with newer types of bulb, and will not stay put, and aiming or tilting of head-lamps is a very hard and often impracticable job. To improve this condition the sale of uptodate replacement units should be pushed.

To obtain data on local conditions in the City of Washington, the Bureau of Standards conducted a test lasting over a week on some 400 cars built by 56 motor-car companies. A number of new cars were included. The results obtained are summarized in the accompanying table.

RESUME OF HEAD-LAMP TESTS GIVING THE PERCENTAGE OF CARS HAVING HEAD-LAMPS IN THE CONDITION NOTED

	Per Cent
Equipment in Good Condition	5.5
Lenses	
Dirty	52.8
Broken	4.3
Loose in Head-Lamp	3.8
Twisted in Head-Lamp	35.8
Reflectors	
Dirty	38.8
Rusty	6.7
Dented	1.7
Bulbs	
Out of Focus	73.2
Blackened	5.3
Too High Candlepower	0.5
Too Low Candlepower	6.7
Head-Lamps	
Not Parallel	23.6
Not Correctly Tilted	46.7
No Outside Focus Adjustment	8.4
Glaring Lights	54.0

Particular attention is directed to the large number of cars with lights out-of-focus, 73.2 per cent of the total. This means not only glare and its attendant danger and discomfort to other motorists and pedestrians, but inadequate roadlight with the consequent element of hazard.

Trend of Legislation

The California motor-vehicle law of 1923 will serve as an example of the detailed requirements now being incorporated in State laws. The following are some of the important points:

(1) Sufficient light to render clearly discernible a person, vehicle, or substantial object 200 ft. ahead

(2) Device shall be constructed, arranged and adjusted so as to give a beam complying with the specifications of the law

(3) Head-lamp devices must be tested and approved before their use shall be lawful. Fifty dollars' fee with application for test

(4) Details of test specified; similar to those of Illuminating Engineering Society's and Society of Automotive Engineers' requirements

(5) If arrested for improperly focused lights, owner will be released if head-lamps are adjusted within 24 hr.

(6) Unlawful to sell a device unless it is ap-

E. S. Faire

R. E. Carlson

proved and accompanied by a complete description and instructions for use, including photographs of the device and the beam pattern on a chart

In an effort to promote uniformity of enforcement of the State laws, responsible State officials of Connecticut, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island and Vermont have formed what is known as the Conference of Motor Vehicle Administrators. A special committee of this conference passes on matters pertaining to head-lamps. Other conferences should be established throughout the Country so that the benefits of this sort of cooperation can be enjoyed more widely.

EDUCATIONAL CAMPAIGN

Provision has been made for the testing and approval of head-lamp devices, efforts are being made by head-lamp manufacturers and engineering societies to improve the quality of and simplify the service required for these devices, and certain State authorities have been and are making serious efforts to have these devices adjusted by motorists. In spite of all this, the great majority of motorists are not adjusting their head-lamps. To focus interest and to secure action on this subject, a national campaign of education has been started to supplement the work already under way.

The work of the enforcement officer is of particular importance. He must understand that bright head-lamps are not necessarily blinding. It is fatal to the success of this movement to require the motorist to dim his lights; dimming when an officer is in sight will not improve lights that may be badly out of adjustment. A better method of enforcement is to require the motorist to adjust his lights within a specified time and report back to the officer with a ticket certifying that the lights have been adjusted.

From an analysis of some 400 fatal accidents last year in Massachusetts it was found that, where head-lights were concerned, 2½ were due to insufficient light to every 1 caused by too bright light. Dimming is a mistaken idea of courtesy. The human eye, marvelous as it is, cannot adapt itself instantly to such a violent change of light intensity as results from dimming. "Don't Dim, Adjust your Headlights."

CAR BUILDERS' RESPONSIBILITY

Responsibility of the car builder should not cease until the new or reconditioned car is delivered to the owner with good head-lamps and the owner understands how to keep them in good adjustment. Letters written to some 50 car producers indicate a great variation in practice on this point, some companies apparently trusting to Providence that the lights adjusted at the factory will still be good when finally turned over to the buyer. Others have provided the machinery for close supervision of head-lamps through their service departments, branches, dealers and garages. These companies deserve the highest praise.

Car builders should furnish adequate but simple instructions for adjustment, preferably using photographs of beam patterns. These directions should be included in instruction-books, service publications and other mediums. Uniform instructions for all cars should be worked out so that the average garage mechanic will have no trouble in adjusting the head-lamps on any car. Factories must spend more money for good head-lamp equipment. Money invested for higher-grade equipment will return a dividend in the reduced cost of service.

R. N. Falge, of the National Lamp Works, and C. A. Michel, of the Guide Lamp Co., spoke briefly after Mr. Carlson's paper. They both said that head-lamp equipment has been improved greatly due to the agitation for better road illumination in the past 6 months.

CHARTING OF SERVICE DATA

Methods for Making Service Information Most Useful to Designer Explained

O. T. KREUSSER

It has been demonstrated that the trend of the automobile industry should be toward the production of better-performing cars at a decreasing over-all cost per mile of transportation. Upon these factors the continued growth of the industry is founded.

One of the essential items in this conception, as brought out by O. T. Kreusser in his address on Providing the Engineer with Service Data To Improve Design, is a satisfactory maintenance service. Such a service means contented users, and hence a greater volume of business for the factory. But the maximum of advantages can never accrue to the car-user without the closest cooperation between the field and the factory; by this means a rational basis for improved design and construction can be made available. To this end an effective means of communication must always be maintained between those in the field and those at the factory. In his address Mr. Kreusser advocated the closest possible contact between the two branches and suggested a simple form of chart for use in plotting the car troubles as they are brought to the service department. The object of the system is to present to the factory engineers danger signals of repeated troubles with certain features of the cars considered.

A chart of this type, as used by the General Motors Research Corporation, was shown by Mr. Kreusser. It was divided into a total of about 125 headings and sub-headings, with a space opposite each item where dots could be placed to indicate the occurrence of the trouble, the idea being to show, not the specific fault, but merely the frequency with which a fault became apparent in a given element in number of cars observed. The following items were included in the chart.

Engine
- Stationary members
- Moving members
- Lubricating system
- Valves
- Induction and exhaust system
- Cooling system

Electrical
- Generating
- Storing
- Starting
- Ignition
- Lighting and signaling
- Wiring

Clutch and Transmission
- Clutch
- Transmission operation
- Propeller-shaft
- Rear-axle operation

Running-gear
- Running-gear
- Frame
- Springs
- Steering
- Braking
- Instruments

Body
Body
Top
Metal

The example cited showed results of 25,000-mile tests conducted by the General Motors Corporation on a number of cars of different makes operated under as nearly identical conditions as possible. The occurrence of faults in each item was represented by a corresponding number of dots properly placed in the lines to show the time during the test-period when the difficulty arose. In such an analysis danger signals are obvious and steps can be taken to remedy the faults. It was pointed out that the design improvements indicated by such a chart do not always coincide with those that would be selected by an engineer who did not have access to such a pictorial summary.

Mr. Kreusser suggested that factory service departments furnish their field stations with charts of some description in order that pertinent information, from the best of sources, can be made available to the plant engineers for their use in modifying features of design when necessary.

In the discussion it was stated that reliable information is difficult to obtain from field service-stations. A. J. Scaife, of the White Motor Co. reported that his company had considered it advisable to send a staff of engineers into the field to collect required dependable data. He said that in his experience about 5 out of each 500 reports supplied by regular service-men had been of practical value.

It also developed during the discussion that cooperation between the factory engineering and the service department is not by any means always lacking. B. B. Bachman, of the Autocar Co., outlined the plan of that company for getting service-men in from the field at frequent intervals for conferences with the factory engineers. He stated that this practice of discussing important problems is productive of much good.

FLAT-RATE SYSTEM ADVOCATED

Improvements in Design to Reduce Maintenance Costs Suggested

Don T. Hastings

In outlining the various steps involved in the general problem of automobile design, construction and maintenance, Don T. Hastings, of Williams & Hastings, Inc., Detroit, stated that certain factors of original design, such as tire-size, wheelbase and weight, are determined by the prices of finished models fixed by factory executives; while other items, such as gear-ratio and engine-power, are settled by competitive conditions applying to cars of the same price-class.

In the original lay-out of a car, it is the duty of the engineer to allot a suitable percentage of the total cost to the various items involved. In this process the maintenance allowance often becomes inadequate to finance properly the most advantageous treatment of maintenance features. Thus a saving in first cost is made at the expense of upkeep. This was given by Mr. Hastings as one of the reasons why certain designs have been seriously at fault from the maintenance point of view. As an example of this, he cited the use of a two-piece malleable-iron rear-axle housing, whereas a pressed-steel housing with suitable shafts would be much superior from the service standpoint, although more expensive in first cost. He also mentioned the reduction in service costs made possible by providing valve-rods and tappets in clusters, by eliminating such features as the full-length sod-pan and by making parts accessible for adjustment or replacement. The use of oversize parts was advocated for installation after wear of bearings in service.

Referring to accessibility and to the common lack of this desirable feature, the speaker recalled an instance where the main bearings could not be adjusted without removing the engine from the frame. Slight changes in design would have remedied the defect, reducing the cost of service greatly. In another car it was impossible to bring the pistons down past the crankshaft, while in a third that was subsequently altered the tappets could not be adjusted without the removal of the vacuum-tank, the carbureter and the manifold.

In concluding his address, Mr. Hastings mentioned the possibilities of reducing maintenance charges by the systematic conduct of the servicing business; this including the keeping of suitable records, the use of the flat-rate system, the economical use of floor space and equipment and the elimination of labor losses due to idleness.

The discussion following this address served to bring out more clearly several of the more important points. All agreed that the use of the flat-rate system should be extended and that the coordination of the several engineering branches of the industry is essential to the most satisfactory functioning. It was suggested that this could be brought about by a closer study of the problems of each department by the members of other departments.

SERVICE THE BIG BROTHER OF SALES

Modern Service Methods Outlined: Training Course for Service Men Described

Selling of service is the real business of an organization, according to W. L. Wise, service manager of the National Cash Register Co., who spoke on the subject of Service. Furthermore, it was the speaker's belief that a company becomes just as big or just as small as the individual service-man. This conception clearly emphasizes the importance of training service-men so that they themselves are sold on the features that they in turn are expected to sell. For, unless they believe the service to be good and the product worthwhile, their chances of convincing others are exceedingly small. It is with these points in mind that the National Cash Register Co. has developed very carefully a system of education and training for the men who act as points of contact between the factory and the users.

Approximately half of this training is mechanical, the other half being devoted to the proper sale of the service. The object of the latter is to instill the idea into the man and then instruct him as to the best methods of passing on his convictions to the users. Efforts are made to assure the service-men of the company's interest and backing. Furthermore, he is impressed with the idea that his own activities have a direct bearing upon the future progress of the company; that is, that he is capable of making or breaking his company's reputation throughout the territory in which he operates. Thus, he is taught to think well and to speak well of his product and to take pride in its betterment by giving to the company any helpful suggestions that may occur to him.

On the other hand, the company endeavors to show the customer that it is proud of the service and of the men who administer it; such pride should result only from a real desire and effort to bring about the condition of highest satisfaction to the user.

The fact that the company sets the price for the repairman's work is invariably passed on to the customer. The prices per hour include the cost of necessary tools. Before a job is undertaken an inspection is made and an estimate of the cost is figured. No elaborate overhaul is attempted without the customer's consent.

It was contended that the expenditure of considerable sums for better service and for the promotion of a closer feeling

of understanding among factory, repairman and customer was amply justified on a basis of business returns.

In conclusion, Mr. Wise summarized as follows the items that a service-man has to sell:

(1) The company and its product
(2) The reasonableness of the guarantee
(3) The necessity for the repair job according to the company's standard
(4) The use of the company's parts
(5) His price
(6) The need for having the machine cared for periodically
(7) The proper use and the avoidance of abuse
(8) The manufacturer's service
(9) Most important, the fact that the service-station is being run for the benefit of and in appreciation of users and not as a means of deriving additional income from them

In illustrating the many interesting points of his address, Mr. Wise showed samples of instruction material, advertising literature and service information forms which are used by his company in maintaining its service department.

ELECTRICAL EQUIPMENT PROBLEMS

Frank Discussion of Conditions Existing in the Field That Should Be Remedied

P. J. DURHAM

One of the most important sessions of the meeting was that at which P. J. Durham, secretary of the Automotive Electric Service Association, and J. W. Tracy, general manager of the North East Electric Co., presented their views on the reasons for, the particularly aggravating points of and possible ways of remedying the unsatisfactory conditions prevalent in the installation and maintenance of electrical equipment of passenger cars. Chairman Bonham introduced the speakers by saying that the problem involved is a tremendous one and worthy of careful thought.

Mr. Durham, who has been engaged for many years in the maintenance of electrical equipment in the field, said that, whereas some repairs can be accomplished easily, those that must be made when the cars are relatively new are peculiarly disturbing to the owners and the repairmen. He agreed in the general opinion that the principal cause of the trouble is "purchasing department engineering," an expression used by W. A. Chryst at the meeting to indicate that too frequently the electrical equipment manufacturers are held down unduly in the matter of the price that will be paid for the articles they produce.

Mr. Durham pointed to the fact that the average man, even though he be familiar with automobile engineering in general, will hesitate to attempt to diagnose an electrical ailment of a car. Of course, much is involved in the work that is beyond the ability of the average mechanic. Head-lamp doors are difficult to remove, it taking hours sometimes to install a 30-cent bulb. Focusing devices become rusted to such an extent as to make them useless. Many reflectors are not what they should be, lenses are not held in fixed positions and in many cases no method is provided in the equipment for aiming the lights. In too many cases it is impossible to make an adjustment that will last long. Head-lamps must be made better and more easily repairable and adjustable.

The speaker referred especially to the poor quality of electrical contacts and the absurdly small screws used in electrical equipment. The terminals of switches, for example, should be not only better but accessible. At the present time, reaching and adjusting switch connections involves physical contortion by the operator in the case of the average car. This sort of thing causes unnecessarily large labor charges. The screws should be at least as large as No. 12 size and be made of brass instead of iron. Poor contact at an ammeter may involve almost endless expensive troubles in various parts of the electrical equipment. Fuses and fuse clips are too flimsy and too small, as well as difficult to remove. In moderate-priced cars the wiring installment is poor, the wires being generally secured at the terminals only. In this connection Mr. Durham said that a standard code of colors for wires would be of great value in locating and remedying circuit troubles. The storage-battery is the source of the greatest annoyance to service-men. Terminals of generous size would aid greatly and better accessibility is needed. Too many types of terminals are used. At the present time the keeping of a stock for battery service involves considerable investment, if slow-moving special sizes are included. In Mr. Durham's opinion, battery containers should be made larger as a general thing, as there is no doubt that the owner will be benefited in many cases by purchasing a larger battery than that furnished with his car. The shape and the design of the generators have been changed so much that in practice the temporary repair of generators has become almost impossible. For this reason the investment required to maintain a rental service is formidable in amount. In many cases inaccessibility of the generator mounting causes too high labor-charges. As a whole, the generator is the most difficult element encountered in the servicing of electrical equipment.

With reference to the whole problem, Mr. Durham said that, to minimize the amount of required repairs, it will be necessary to improve the design of, materials for and workmanship of electrical equipment. He feels that electrical connectors of the detachable type are unnecessary on head-lamps, as the latter are rarely removed from the car. These connectors cause annoyance because they are small, hard to manipulate and inaccurate. The electrical connections between the wire and the connector and between the plug and the socket are not sufficiently dependable. A better form of connector or splice should be provided and installed under the hood or inside of the head-lamp. Trivial troubles stall cars. Generators have had to be reconditioned simply because of flimsy connections in the charging line.

Mr. Tracy explained the conditions that surrounded the original installation of electrical starting and lighting units on cars many years ago. Little time was available for redesigning engines and chassis for accommodating this equipment, and therefore the servicing of the parts involved was handicapped from the start. Room for improvement in this respect still exists. Odd and unusual sizes and shapes of bolts, nuts and screws must give way to practicable commercial standards. Intricate operations and complicated circuits will have to be simplified and the repairing of the equipment with simple tools fully considered fundamentally in the design of the apparatus. Increased labor-charges for repairs due to the unsatisfactory performance of inadequate equipment should not be tolerated. The battery is often dismissed by the car-maker with slight consideration. A labor cost of $6 is sometimes involved in installing a 6-cent brush on a generator. In some cases the radiator must be removed in this operation. A repair-parts stock at the present time includes over 1000 different types of electrical equipment. One electrical manufacturer has over 400 different armatures to service, these being characterized by very minor differences. Changes should be avoided when possible; and when they have to be made they should not interfere with interchangeability. Satisfactory service cannot be had in the field if the field is compelled to serve as a "laboratory." At the present time many service-stations are carrying obsolete parts. The designing engineer can be most effective by studying the conditions the field men encounter and cooperating fully with these men. Design of new apparatus and changes in design

[illegible] by a study of service de[illegible] A minor change in the size or shape of [illegible] may call for radical changes in the testing equipment throughout the entire field of the service organizations.

H. Packer who presented at the Service Meeting of the Society held in Chicago last February a paper relating to the general problem discussed at this meeting, reiterated his opinion that not enough attention has been paid to the men [illegible] engineering to give service in the towns and small cities throughout the Country. Mr. Conner said that no trouble will be encountered with the wiring system in motor vehicles if proper installation is made in the first place.

Chairman Bentum recommended that various units of starting equipment be designed so that they cannot be assembled on a car in any way except the right way and agreed that the best efforts of all concerned should be exerted to assist the users and repairmen in the "nick" towns, as suggested by Mr. Kettering, inasmuch as 65 per cent of the product of the automobile factories is purchased by people residing in or near the small cities and towns of this Country.

FLAT-RATES HELPFUL

Engineering Cooperation Urged for the Success of the Flat-Rate Service

J. W. Lord

In a paper entitled Ways in Which the Engineer Can Cooperate To Make Flat-Rate Service More Successful, J. Willard Lord, service manager of the Harrolds Motor Car Co., called attention to the importance of the automobile maintenance industry and stated that service and maintenance establishments are being conducted more and more along modern, straightforward and honest business lines. As an evidence of such improvement he cited the introduction of flat-rate charges for repairs and the establishment of shop standards for measuring the performance of mechanics. With reference to effecting even greater improvement, he expressed the belief that the coordination of engineering with service is bound to lead to the production of vehicles that will give greater satisfaction to the buying public than ever will be possible under the general conditions of largely [illegible] engineering effort existing today.

Mr. Lord suggested that engineers cooperate with the [illegible] in their endeavor to reduce maintenance charges, by giving consideration at the time of designing the vehicle to (a) tools for repair work, (b) degree of accessibility as an aid to repair and (c) facility of removal and replacement of parts. He recommended the holding of service conventions at the factories to discuss the matter of repair tools, and urged the application of engineering thought to the production of parts.

PNEUMATIC SHOCK ABSORPTION

Detroit Section to Hear Paper on Device Using Air as Shock-Absorbing Medium

[illegible] will illustrate the paper on Shock Absorbers which J. M. McElroy, chief engineer of the Westinghouse Air Spring Co., will present before the Detroit Section at its [illegible] meeting on Dec. 6.

Mr. McElroy will cover the patent history and early development of the device before going on to a discussion of the present suspension and what it does theoretically. Axle movement, with and without the air spring, will be taken up next, followed by a study of the relation of axle movement to riding comfort. Mr. McElroy's paper will also include a thorough treatment of the design, manufacture, installation and servicing of the air spring.

The Dec. 6 meeting of the Detroit Section will be held, as usual, in the General Motors Building at 8 o'clock, preceded by a dinner at 6:30 p. m.

CRANKCASE IMPROVEMENTS ADVOCATED

Accessible Oil-Drain and Other Design Changes Urged at Dayton Service Meeting

T. A. Waerner

In discussing the subject, What the Engineer Can Do To Help the Public, T. A. Waerner, engineer with the Tide Water Oil Co., treated the matter of crankcase-oil dilution and mentioned three points to be considered by engineers for bringing about improvement in this regard. These points relate to design and are as follows: (*a*) suitable location of oil-drain; (*b*) arrangement of parts to facilitate cleaning them after the oil has been drained; (*c*) the design of crankcase oil-sump to reduce dilution.

Mr. Waerner emphasized the necessity for draining the crankcase in both summer and winter at frequent intervals and argued that this operation would be conducted more frequently if cars were designed so as to make it less difficult to accomplish. Calling attention to the decision of the Standards Committee of the Society that no definite type of oil-drain should be standardized but that a suitable oil-drain of ample dimensions, operable from a point under the hood, should be installed, he stated that very few factories produce cars whose engines are so equipped.

As a universal practice in all designs, consideration was urged of the arrangement of the oil-pump screen in such a way as to make possible the removal of the screen independently of the oil-pan. Mr. Waerner took up in some detail the process of combustion as affected by the structure of various types of gasoline and entered into a discussion of the factors responsible for crankcase dilution and its damaging effects on engines. He called attention to the incongruity of the variety of crankcase capacities, these ranging from 4 to 14 qt., and recommended standardizing on two capacities, one measure for four-cylinder engines and the other for six and eight-cylinder engines.

ANNUAL MEETING IN DETROIT

Arrangements Presage Extensive Program and Large Attendance

Arrangements for the Annual Meeting in Detroit, Jan. 22 to 25, are progressing rapidly and a number of the preliminary details can be announced at this time. It is planned to make the program of papers the most comprehensive of any meeting ever held by the Society. This will necessitate the scheduling of simultaneous sessions, but the topics will be arranged so that very little conflict will occur between papers on related subjects that are of direct interest to special groups of the membership. All sessions will be held in the massive building of the General Motors Cor-

poration. Morning meetings will be held in the auditorium which is capable of seating 1100 persons. Papers of general interest will be given at these morning sessions and it is probable that no meetings will be run simultaneously with them. Afternoon and evening sessions will be held in quarters on the 15th floor of the General Motors Building, these being provided through the courtesy of the General Motors Corporation. Facilities are available in the building for telegraphic service, purchase of railroad transportation and the serving of excellent cafeteria meals. It is unlikely that any better place could have been chosen for the Annual Meeting anywhere in the Country.

Committee Organization

Mason P. Rumney, chairman of the Meetings Committee of the Society, has chosen several sub-committees of the general committee to assist in making the arrangements for this big undertaking. The personnel of the committees so far appointed is as follows:

ENGINE, FUEL AND CHASSIS PROGRAM

Thomas J. Litle, Jr., *Chairman*

L. C. Freeman — W. R. Strickland
George L. McCain — J. G. Vincent
F. E. Watts

PRODUCTION PROGRAM

K. L. Herrmann, *Chairman*

Committee being organized

AERONAUTICAL PROGRAM

Prof. E. P. Warner, *Chairman*

Committee being organized

TRUCK AND BUS PROGRAM

F. C. Horner, *Chairman*

Committee being organized

BODY ENGINEERING PROGRAM

A. L. Knapp, *Chairman*

Dean Baskerville — Otto Graebner
A. A. Cripps — W. H. Jones
William Davis — R. A. LaBarre
A. J. Fisher — J. W. Votypka
Kingston Forbes — J. F. Wilson

Each of these committees will be responsible for the program of papers given in its respective field. All committees are now functioning and the program is practically closed. A special issue of the *Meetings Bulletin* will reach the members about Dec. 15 and this will contain the tentative program. Present plans call for four sessions on engines, fuels and chassis; three body meetings are scheduled; aeronautical subjects will require two sessions; two meetings will be devoted to trucks and buses; and at least two production meetings will be held.

Subjects of Annual Meeting Papers

Present plans as contemplated by the several committees on papers call for discussion of the following subjects:

Engine, Fuel and Chassis
- Steam cooling systems
- Radiator design
- Carbureter characteristics
- Anti-knock fuels
- Detonation control
- Crankcase-oil dilution and engine wear
- Brake testing
- Constant-compression engines
- Air-cleaners
- Manifold design
- Fuel volatility

Aeronautics
- Design of the Shenandoah (ZR-1)
- Engine design for reliability
- Research work of the National Advisory Committee for Aeronautics
- Design of commercial aircraft
- Operating experience of the Postal Service

Truck and Motorbus
- Motorbus and railroad transport coordination
- Operation of urban and interurban motorbus systems
- Motorbus transportation and its relation to traffic

Body Engineering
- Nickel plating
- Black enameling on non-ferrous metals
- Upholstery fabrics and styles
- Casein glues
- New body constructions
- Detrimental effects of accelerated drying

Subjects for the production meetings have not been selected as yet. A large number of car and parts companies are being asked for papers on manufacturing problems and the program is certain to be of interest to factory men.

General Motors Building, Detroit, Where the 1924 Annual Meeting Will Be Held

Standards Committee Meeting

Many important recommendations will be voted on by the Standards Committee at its annual meeting which will be held in Detroit on Tuesday, Jan. 22. This meeting will open the activities of the 4-day gathering of the Society.

It is probable that the Annual Business Meeting and election of officers will be scheduled for Tuesday evening, Jan. 22. This meeting is expected to be a very important one because of the probability of there being a general discussion of relations between the parent Society and the Sections. Following the conclusions of the business program and the address of President Alden, a representative of the Ordnance Department of the United States Army will present an illustrated talk on the remarkable development of ordnance materiel, both general and automotive, that has been accomplished in the past year or two.

Reduced Railroad Fares

It will be possible for members of the Society to secure reduced railroad-fares to the Annual Meeting in Detroit. The plan will operate the same as that used at past Annual Meetings and will entitle members using the proper certificates to buy return tickets from Detroit to their homes at half-price. Complete details of this reduced-fare plan will be published in the *Meetings Bulletin* and in the January issue of The Journal.

It is not too soon to warn members that hotel facilities in Detroit will be taxed during the week of the Annual Meeting. Detroit's Automobile Show will be in progress during the meeting period and will attract many people to the city. Arrangements are being made with some of the

[illegible] to hold rooms for our members until Jan. 1, and a list of hotels reservations will be announced in the near future. Meantime there is nothing to prevent far-sighted members from writing direct to the hotels and making reservations at this early date. The Meetings Committee is able to give its stamp of approval on the following hotels:

Hotel Statler
Hotel Tuller
Wolverine Hotel
Fort Shelby Hotel

The Hotel Statler has set aside a part of its accommodations for Society members so that it is advisable to state to your friends that you will attend the Annual Meeting of the Society.

GAY CARNIVAL IN DETROIT

Famous Social Function Revived as the Entertainment Feature of Meeting

Worshippers of Terpsichore and adherents of syncopation and gay revelry will listen with tinkling enthusiasm to the announcement that the Society's Carnival has been revived! At the October meeting of the Council, the Meetings Committee made the suggestion that this popular social event be scheduled as the entertainment feature of the Annual Meeting in Detroit in January. Approval was given by the Council and the following large committee of Detroit enthusiasts is now busily laying plans for one of the finest social gatherings ever held by the Society.

1924 CARNIVAL COMMITTEE

George H. Hunt, *Chairman*

Fred A. Cornell	G. E. Goddard
V. C. Cramer	B. G. Koether
W. P. Culver	W. C. Little
H. T. Ewald	Neil McMillan, Jr.
R. K. Floyd	M. P. Rumney

Oriole Terrace, Detroit's largest and finest dine-and-dance establishment, has been chartered for the night of Jan. 23 for this great party. It will accommodate 750 people, the music will be strummed and syncopated by an unusually fine orchestra headed by a gentleman named Theis, whose abilities have just about captured all of the fox-trotters in the Motor City.

An innovation is planned in connection with the 1924 Carnival; all present will be seated at reserved tables as in the usual dinner-dance establishment. Applications for tables will be included with the issue of the *Meetings Bulletin* to be mailed about Dec. 15 and reservations will be made in the order of receipt, the better table locations going to the early comers. Moral: Send yours in promptly.

ANNUAL DINNER AT HOTEL ASTOR

A. G. BERGMANN

Transferring the Annual Meeting to Detroit will not affect that great institution, the Annual Dinner. This important event will be held at the Hotel Astor, Thursday evening, Jan. 10, starting at 6:30 o'clock. A. C. Bergmann has been appointed chairman of the committee that will be in charge. He promises to create an unusually fine atmosphere of good fellowship. Special care will be taken to see that folks get acquainted and have an enjoyable evening.

As announced in the last *Meetings Bulletin*, the Society has been successful in securing E. S. Jordan, more intimately known as "Ned," as toastmaster for this occasion. Those who know Ned Jordan and have enjoyed his genial humor and sound sales logic will appreciate that the work of the helmsman will be handled satisfactorily.

Only two speakers will be on the program. We are fortunate in having secured Dr. M. L. Burton, president of the University of Michigan, a speaker noted for his forcefulness, interesting personality and his ability to leave a message that men will think about long after the day of his address. He has chosen as his subject That Mind of Yours. You may be sure that he will tell you some things about it that will make you have a greater respect for the important problems facing the world today and your responsibility in being fit to solve them.

Although we have received the tentative acceptance of another speaker, whose high standing as an authority on commerce and a statesman is internationally acknowledged, it is impossible to make any definite announcement until a later date, owing to the fact that his engagements with national affairs might cause an unexpected interference.

Dinner ticket applications will be included with the next issue of the *Meetings Bulletin*, reaching the members about Dec. 15. Seats will be reserved in the order of receipt of these applications, preference as to location being accorded the early comers.

Applicants *for* Membership

The applications for membership received between Oct. 15 and Nov. 15, 1923, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

AKRON-SELLE CO., *Akron, Ohio.*

ANDERSON, M. C., engineer, Lee Trailer & Body Co., *Chicago.*

ANDERSON, O. L., layout draftsman, Rickenbacker Motor Co., *Detroit.*

AYERS, DONALD J., chief engineer, Anthony Co., *Streator, Ill.*

BABINGTON, ALFRED EDWARD WILFRED, automobile broker, 436 Yonge Street, *Toronto, Ont., Canada.*

BARNETT, JOHN H., advertising manager, Robert H. Hassler, Inc., *Indianapolis.*

BEST, FRANCIS CLARENCE, chassis draftsman, Packard Motor Car Co., *Detroit.*

BITZER, HARPER G., student, Ohio State University, *Columbus, Ohio.*

BLACKMAN, EDWARD C., assistant in experimental department, American-La France Fire Engine Co., *Elmira, N. Y.*

BROOKS, MELVIN S., Ford Motor Co. of Canada, Ltd., *Ford, Ont., Canada.*

BRYAN, HARRY F., carbureter engineer, Ensign Carburetor Co., *Los Angeles.*

BRYSON, WILLIAM R., designer, Rickenbacker Motor Co., *Detroit.*

CAIN, JOSEPH I., student, University of Illinois, *Urbana, Ill.*

CARLSON, CLIFFORD E., chemist, Remington Arms Co., *Ilion, N. Y.*

COURTNEY, HARRY V., student, Stevens Institute of Technology, *Hoboken, N. J.*

CRAWFORD, JOSEPH T., manager of automobile sheet department, American Rolling Mill Co., *Middletown, Ohio.*

CUNNINGHAM, JOHN HUNTER, chief engineer and designer, W. H. Dorman & Co., Ltd., *Stafford, England.*

FEZANDIE, EUGENE, instructor, Stevens Institute of Technology, *Hoboken, N. J.*

FORS, ARTHUR R., production engineer, Continental Motors Corporation, *Detroit.*

FULLER, WAYNE R., manager of industrial sales, Pratt & Lambert, Inc., *Buffalo.*

GAUTHIER, DONAT A., assistant mechanical superintendent, Ottawa Car Mfg. Co., *Ottawa, Ont., Canada.*

GOODIER, HOMER WADSWORTH, mechanical engineer, Atmospheric Nitrogen Corporation, *Syracuse, N. Y.*

GRANGER, HENRY R., student, Cornell University, *Ithaca, N. Y.*

HALL, FRED A., draftsman, Yellow Coach Mfg. Co., *Chicago.*

HALLIBURTON, VIRGIL FRANCIS, student, Massachusetts Institute of Technology, *Cambridge, Mass.*

HEINTZ, LEO I., president, Heintz Mfg. Co., *Philadelphia.*

HOWARD, H. F., manager of service department, Wire Wheel Corporation of America, *Buffalo.*

JACKMAN, CHESTER C., works manager, Stanley Motor Carriage Co., *Newton, Mass.*

JACOBS, W. T., chief engineer, Stephens Motor Car Co., *Freeport, Ill.*

KRIETER, HARRY R., student, University of Michigan, *Ann Arbor, Mich.*

LIDDLE, GEORGE D., student, Ohio State University, *Columbus, Ohio.*

MILLER, JOHN H., superintendent, International Motor Co., *Allentown, Pa.*

MOORE, HAROLD M., student, Ohio State University, *Columbus, Ohio.*

MORRIS, C. A., manager and proprietor, Morris Motor Car Co., *Waterloo, Iowa.*

NAGLE, L. S., sales engineer, Pacific coast division, Hyatt Roller Bearing Co., *San Francisco.*

NEWMAN, ALEXANDER, student, Armour Institute of Technology, *Chicago.*

OSWALT, ELMER J., student, Ohio State University, *Columbus, Ohio.*

PEARLSTONE, PAUL, student, Sheffield Scientific School, *New Haven, Conn.*

PERESUTTI, LUIS, student, Ohio State University, *Columbus, Ohio.*

QUIMBY, GEORGE WILLIS, automobile body engineer, Fox Motor Car Co., *Philadelphia.*

RALLS, GEORGE H., sales manager, Gabriel Mfg. Co., *Cleveland.*

RITTER, RALPH B., mechanical engineer, A. O. Smith Corporation, *Milwaukee.*

SAGE, FRED L., engineer, Mason Motor Truck Co., *Flint, Mich.*

SCHERMERHORN, CHARLES B., student, University of Michigan, *Ann Arbor, Mich.*

SIMPSON, ANDREW, instructor, Swarthmore College, *Swarthmore, Pa.*

SIMPSON, THERON B., assistant tool engineer, Motor Wheel Corporation, *Lansing, Mich.*

SKLENAR, FRED H., draftsman, Beneke & Kropf Mfg. Co., *Chicago.*

SMILLIE, CHARLES M., JR., efficiency and methods engineer, Ternstedt Mfg. Co., *Detroit.*

STARING, W. H., vice-president, Perfection Heater & Mfg. Co., *Cleveland.*

STILLE, ERNST H., draftsman, Sayers & Scovill Co., *Cincinnati.*

SWANSON, VERNER J., chief engineer, A. L. Powell Power Co., Inc., *Cleveland.*

TIBBETS, FRED H., JR., student, Ohio State University, *Columbus, Ohio.*

TRUSCOTT, PERCY J., teacher, Arthur Hill Trade School, *Saginaw, W. S., Mich.*

TYLER, RALPH H., general superintendent, Herbrand Co., *Fremont, Ohio.*

VANDERWALL, THEODORE, engineer, C. M. Hall Lamp Co., *Kenosha, Wis.*

VARADY, JOHN C., student Ohio State University, *Columbus, Ohio.*

VIGMOSTAD, TRYGVE, body engineer, Stephens Motor Car Co., *Freeport, Ill.*

WATERS, MAURICE W., clerk in traffic department, Detroit, Toledo & Ironton Railroad Co., *Detroit.*

WILLIAMS, RICHARD C., sales engineer, E. I. duPont de Nemours & Co., *Parlin, N. J.*

WILLITS, S. R., sales engineer, Beneke & Kropf Mfg. Co., *Chicago.*

WILSON, FRANK E., student, Ohio State University, *Columbus, Ohio.*

WOODWARD, IRVING C., mechanical engineer, Prest Barty Axle Corporation, *Syracuse, N. Y.*

WRIGHT, PAUL D., student, Ohio State University, *Columbus, Ohio.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Oct. 10 and Nov. 10, 1923. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

[illegible] (E S) student, University of Cincinnati, Cincinnati, Ohio. (mail) [illegible] Ingalls Street.

[illegible] C. (E S) student, Ohio State University, *Columbus, O.*, (mail) 68 Seymour Avenue.

[illegible] Robert Hickman (A) owner, Blackburn Oil Co., *Spartanburg, S. C.*, (mail) P. O. Box 51.

[illegible] M. (A) general manager, Templar Motors Co., Cleveland, Ohio, (mail) 1261 Wood Road, *Lakewood, Ohio.*

[illegible] Ivan (M) engineer, Self-Feeding Vaporizer Corporation, 1737 Broadway, *New York City.*

Brogan, G. W. (A) advertising manager, Black & Decker Mfg. Co., *Towson, Md.*

[illegible] William Robert (A) engineer, Hole & Bryant, 31, East [illegible] Street, *Somerset, England.*

Cammann, Oswald, Jr. (J) engineer, Davis Sewing Machine Co., *Dayton, Ohio.* (mail) 225 North Main Street.

Case, Harry R. (J) inspector and tester of electric trucks, Ward Motor Vehicle Co., Mount Vernon, N. Y., (mail) 209 Johnson Avenue, *Jersey City, N. J.*

Chapin, Kenneth L. (M) research engineer, Standard Textile Products Co., New York City. (mail) The Whittier, Burns Drive, *Detroit.*

[illegible] Joseph F. (M) chief engineer, Miller Taylor, Inc., 1108 Land Title Building, *Philadelphia.*

Christie, L. C. (M) chief engineer, Spicer Mfg. Corporation, South Plainfield, N. J. (mail) 143 Jackson Avenue, *Plainfield, N. J.*

Cook, Guy J. (A) Eastern manager of sales, Westinghouse Union Battery Co., Sewickley, Pa., (mail) 376 North Fullerton Avenue, *Montclair, N. J.*

Crane, Richard B. (M) chief engineer, Western Electric Co., Inc., 463 West street, *New York City.*

[illegible] Tool Co. (Aff) *Jamestown, N. Y.*
[illegible] *Switzerland, C. H.*

Demellier, Henry A. (A) tool supervisor, Gould & Eberhardt, Newark, N. J. (mail) 246 Lincoln Place, *Irvington, N. J.*

[illegible] Charles L. (A) sales engineer, S K F Industries, Inc., 165 Broadway, *New York City.*

[illegible] Henry R. (M) cable engineer, Whitney Blake Co., 105 [illegible] Street, *New York City.*

Dorsey, Hugh C. (M) assistant general manager, Olds Motor Works, *Lansing, Mich.*, (mail) 616 South Jenison Avenue.

[illegible] F. M. (A) chief engineer, Tennessee Mfg. Co., 6307 Fort [illegible], *Detroit.*

Farris, L. E. (J) mechanic, Yellow Cab Mfg. Co., 5801 West [illegible] Avenue, *Chicago.*

[illegible] William (J) test engineer, Standard Oil Co. of [illegible], *Richmond, Calif.*, (mail) 32 East 20th Street.

[illegible] (M) engineering department, National Lamp Works, [illegible], *East Cleveland, Ohio.*

[illegible] A. L. (M) sales engineer, Standard Axle & Spring Co., Wilkes-Barre, Pa., (mail) 24 West Main Street, *Mauch Chunk, Pa.*

[illegible] (Affiliate) (J) draftsman, Wooster Elevator Co., Inc., [illegible] City, (mail) 41 Monroe Street, *Brooklyn, N. Y.*

[illegible] C. Wesley (A) sales manager, National Lead Co., 111 [illegible] Street, *New York City.*

[illegible] (M) 1165 Virginia Avenue, *New York City.*

[illegible] W. T. (M) vice-president and general manager, Depot Motor [illegible], Inc., 730 [illegible] street, *Chicago.*

Halliburton, Virgil Francis (E S) student, in mechanical engineering, Massachusetts Institute of Technology, *Cambridge, Mass.*, (mail) Box 294, Massachusetts Institute of Technology.

Hansen, H. A. (M) manager, Stromberg Motor Devices Co., 2739 Woodward Avenue, *Detroit.*

Keegan, Curtis W. (A) district manager, Cincinnati Ball Crank Co., Cincinnati, (mail) Room 5-107 General Motors Building, *Detroit.*

Kelly, Edwin H. (A) general sales manager, Dunlop Tire & Rubber Co. of America, *Buffalo.*

Kizer, Karl K. (A) chief engineer in cab department, Bauer Mfg. Co., 111 East 30th Street, *Chicago*, president, Kizer Equipment Co., 3110 South Michigan Avenue, Chicago.

Leach, Albert E. (M) manager of drafting room, Studebaker Corporation of America, Piquette Avenue, *Detroit.*

Lukee, Fred (J) experimental engineer in charge of dynamometer room, A. C. Spark Plug Co., *Flint, Mich.*, (mail) 609 Mary Street.

McKelvy, Tom M. (A) inventor and designer, McKelvy Rotary Valve Co., Inc., *Fresno, Cal.*, (mail) St. Andrews Apartments.

McMahon, John F. (M) mechanical superintendent, Yellow Taxi Corporation, *New York City*, (mail) 640 West 153rd Street.

Main, Frank L. (A) assistant sales manager and experimental engineer, Hayes Wheel Co., Jackson, Mich., (mail) 3-258 General Motors Building, *Detroit.*

Meese, Horace S. (M) transportation consultant, Commercial Truck Co., *Philadelphia*, (mail) 260 South 18th Street.

Melheim, H. W. (J) student, Carnegie Institute of Technology, *Pittsburgh, Pa.*, (mail) 420 South Dithridge Street.

Merritt, Ralph V. (A) American Steel Chase Co., New York City, (mail) *East Williston, N. Y.*

Monjar, J. G. (A) sales representative, Hyatt Roller Bearings Co., *Detroit*, (mail) 1381 Coplin Avenue.

Neale, Fred (M) designer, Northway Motor & Mfg. Co., *Detroit*, (mail) 12747 Myers Road.

Nelson, Reginald (A) chief mechanic, Borden Farm Products Co., *Brooklyn, N. Y.*, (mail) 196 Greene Avenue.

Newman, Alexander (E S) student, Armour Institute of Technology, *Chicago*, (mail) 343 North Central Avenue.

Oestermeyer, Carl F. (M) electrical engineer, Willard Storage Battery Co., *Cleveland.*

Ofensend, Chase F. (A) mechanical engineer, Miller Rubber Co., *Akron, Ohio.*

Ogawa, Yoshio (J) student, Tri-State College of Engineering, *Angola, Ind.*, (mail) P. O. Box 214.

Pratt, Theodore D. (M) general manager, Motor Truck Association of America, 1819 Broadway, *New York City.*

Radford, W. H. (M) vice-president, Balboa Motor Corporation, *Detroit*, (mail) 1691 West Euclid Avenue.

Rushmore, S. W. (M) owner, Rushmore Laboratory, *Plainfield, N. J.*, (mail) 694 Belvidere Avenue.

Satterthwaite, George (M) manager of steel works, Henry Disston & Sons, *Tacony, Philadelphia.*

Shield, John (A) assistant engineer, Northern Electric Co., Ltd., *Montreal, Canada*, (mail) 79 Rozel Street.

Shimer, William Robert (M) metallurgical engineer, Bethlehem Steel Co., *Bethlehem, Pa.*

Spofford, Harry H. R. (A) mechanical engineer, Copper & Brass Research Association, 25 Broadway, *New York City.*

Starck, W. A. (A) engineer, Badger Mfg. Corporation, 156 Clinton Street, *Milwaukee.*

Strom, George A. (A) vice-president, U. S. Ball Bearing Mfg. Co., 1535 Palmer St., *Chicago.*

Swantesson, C. A. (A) service manager and service engineer, T V T Motors Corporation, *City of Washington*, (mail) 3213 33rd Place, Northwest.

Thomson, Horace L. (A) research, *Leland, Mich.*

Thomson, William G. (A) automobile mechanic, Consumers Ice Co., *San Francisco*, (mail) 161 Chilton Avenue.

Varady, John C. (E S) student, Ohio State University, *Columbus, Ohio*, (mail) 133 Chittenden Avenue.

Votypka, John W. (M) body engineer, Towson Body Co., *Detroit*, (mail) 2664 Northwestern Avenue.

Wall, Max (A) engineer, Max Wall & Co., 53 Tory Street, *Wellington, New Zealand.*

Wharam, John J. (M) assistant engineer, Lincoln Motor Co., Dearborn, Mich., (mail) 2676 Montclair Avenue, *Detroit.*

Winzenburg, Fred C. (A) commercial artist, Winzenburg Artists, 410 South Michigan Avenue, *Chicago.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

INDEX TO VOLUME XIII, JULY-DECEMBER, 1923

	PAGES
July	1-108
August	109-176
September	177-254
October	255-354
November	355-442
December	443-540

A

ABELL, R, ON SINGLE-VALVE INTERNAL-COMBUSTION ENGINE DESIGN AND OPERATION 301
Acceleration force for one cylinder 486
Accident prevention 365
Acetone in composite engine-fuels, use of (R F Remler) 23
Adjustment of wheel parts 59

Aeronautics

American safety code 150
Helium in airships 400
Agricultural Equipment Division, S A E, report at semi-annual meeting 79

Agricultural Products

Marketing of 449
Price of 460
Air-cooled automotive engines (C P Grimes) 125
Air-cooled passenger-car engines, aircraft-engine practice as applied to 16
Aircraft-engine practice as applied to air-cooled passenger-car engines (S D Heron) 16
Air-cushion tire session at semi-annual meeting 66

Airplanes

Commercial travel 513
Development of commercial 511
Inexpensive construction of paramount importance 511
Must carry greater pay-load with same power 511
Races at St. Louis 400

Airships

Helium in 400
Photoelastic method applied to rigid research 497
The model 497

Air-temperature and fuel-viscosity effects 9
ALLEN, R J, ON TESTING MATERIALS FOR AUTOMOTIVE PARTS 39
Aluminum-alloy pistons 38
American aeronautical safety code 150
American Electric Railway Association annual meeting 375
American Petroleum Institute meeting announced 516
American workingman 437
Analysis of shape of pressure-time curves 115
Analysis of various four-wheel brake designs (C W Jacobs) 512
Annual dinner announced 532

Annual Meeting, S A E

Announced 530
Carnival announced 532
Committee organization 531
Reduced railroad fares 531
Standards Committee meeting 531
Subjects of papers 531
Application of conveyor equipment to a small production plant (H P Harrison) 357, 432, 479
Application of the Diesel engine to the yachting field (George A Colley) 450
Application of research 369
Automobile head-lamp regulation (James J Shanley) 249
Automobile service (C F Kettering) 523

Automobiles

Accessibility and repairs 93
Adjustment of wheel parts 59
Air-cooled engines 125
Aircraft-engine practice as applied to air-cooled engines 16
Application of conveyor equipment to a small production plant 357
Balloon tires are here to stay 425
Body nomenclature 437
Builders' responsibility for head-lamps 527
Comparative merits of steel disc and wood wheels 207
Conditions of manufacture 384
Cooling capacity of radiators 30
Cooperation in the solution of service problems 384
Deceleration tests 495
Decelerometer for testing brakes 499
Dynamic tests of parts 39
Economic motor-fuel volatility 3
Effects of air-cushion tires on operation 44
Effects of air-cushion tires on speed and steering 44
Engineers vitally concerned in used-car problem 521
Equalization of brakes 56
Factory engineer's influence 94
Final inspection line 365
Fire hazards of 247
Four-wheel braking systems 55
Fundamental characteristics 257
Fundamentals of low-pressure air tires considered 41
Galloping and front-wheel toe-in 46
Head-lamp regulation 249
Illumination diagrams for showing head-lighting device performance 333
Importance of better head-lamps and proper adjustment 25, 221, 520
Low-pressure tires applied to 47
Mechanical braking on four wheels as a present necessity 55, 216
More comfortable interiors 383
No profit in used car for dealer 520
Operative smoothness 59
Packard single-eight 257, 485
Painting the hood, fender and wheels 519
Principles of servo-brake 58
Prolongation tests of parts 39
Providing engineer with data to improve design 527
Public's and car-builders' attitude toward balloon tires 461
Radiator capacity and engine horsepower 30
Radiator sizes in practice 31
Rebound checks 464
Reinforcement and steering ability 57
Relation of the engineer to the used-car problem 520
Renault mechanical four-wheel braking system 57
Repair parts 94
Servo-brake adjustment 58
Shock-absorbers needed with balloon tires 426
Shock-absorbers should have neutral zone 521
Shock-absorbing devices 446
Shoeing with low-pressure air 41, 213
Side-sway 46
Specifications of Packard single-eight 257
Spring-movement and vibration study 445, 521
Stanton machine for testing parts 40
Steering-arm mounting 56
Stopping ability 315
Summer road-tests 4
Testing materials for parts 39
Testing of materials and its effect on engineering 296
Traction and braking control 45
Transportation unit 61
Types of brake construction 56
Vibration tests 448
What air-cushion tires do for 43
What part the engineer can play in reducing repair costs 525
Winter road-tests 5
Winter tests show lower mileage with heavy fuels 87

Automotive Industry

Developments in production grinding 387, 431, 475
Engineering fields 385
Increased cooperation needed 385
Magnitude of 494
Observations on the field in Europe 493
Relation of manufacturer to motor transport 516
Auto-suggestion, value of 368

Axle and Wheel Division, S A E

Activities 344
Personnel 408
Report at semi-annual meeting 79
Unaccepted recommendation 83

Axles

Bevel-Gear and chain drives 151
Chain drive 151, 166
Construction 273
Double-reduction drive 153, 164
Full-floating 155
Internal-gear drive 152, 160
Rear 274
Rear for trucks 151, 234
Semi-floating 153
Tilt of front 457
Tilt and wheel alignment 457
Worm-drive 152, 156

B

Babbitt the ideal lining 424
BACHMAN, B B, ON COOPERATION IN THE SOLUTION OF SERVICE PROBLEMS 384
BACHMAN, B B, ON SERVICE FROM THE ENGINEER'S VIEWPOINT 60

Ball and Roller Bearings Division, S A E

Activities 509
Report at semi-annual meeting 80

Balloon Tires

Acceleration, effect on 462
Analysis of opposition to 462
Application 463
Distinct type 462
Fundamentals considered 41
Here to stay 425
Interfere with wheel-housings 522
No tread cuts 426
Operation, effect on 44
Public's and car-builders' attitude toward 461
Rebound checks 464
Safety of 426
Shock-absorbers required with 426
Size nomenclature 49
Speed, effect on 44
Sterling, effect on 44
Usage 464
Why, improve braking 523
BANHAM, W J L, ON COORDINATION OF MOTOR-TRUCK AND RAILROAD TRANSPORTATION 122
Bank funds, German 420

Bearings

Babbitt the ideal lining 424
Precision for engine crankshafts 424
Thickness and resistance of oil-films in high-speed 101
Benzol as engine fuel 379

Benzol

Performance 379
Tests 379
Bevel-gear and chain drives 151
Blow-outs 45

Bodies

Chassis requirements and 185
From ground color to finish 519
Handling the trimming of 363
Nomenclature 437
Preparing for the color coats 518
Repainting and refinishing of automobile 518
Body nomenclature 437
BOSWALL, R O, ON THICKNESS AND RESISTANCE OF OIL-FILMS IN HIGH-SPEED BEARINGS 101
BOUTON, EUGENE, ON WAGE-INCENTIVE SYSTEMS 380, 432, 480
Brakes (W S James) 522

Brakes

Accurate performance tests 522
Actuating cylinders of four-wheel 314
Advantages of hydraulic system 316
Analysis of various four-wheel designs 512
Anchor block improves external power 512
Control 316
Decelerometer for testing automobile 499
Design and construction of mechanism 397
Desirable features of design 396
Disadvantageous features of four-wheel 313
Equalization 56, 271
Equalization of four-wheel 315
External versus internal 313
Facility of action 271
Foreign equalization practice 56
Four-wheel as a present necessity 55, 216
Four-wheel design 314
Functions 395
Fundamental requirements 268
Future, probably hydraulic 512
Hand, and lubrication 59
Hydraulic four-wheel, for automotive vehicles 313
Hydraulic system of four-wheel 312
Internal and external contrasted 512

C

Cam grinding 385
474
Camshafts, Distortion from heat-treatment 336
Camshaft specifications 140

Carburetors

Adjustment 96
Specifications 140
Design of commercial trucks 492
Control of motor trucks 460
Cams 151, 166
Cams, Discussion on Critical Study of Modern Automotive-Vehicle Steering Systems 205
Cast and heat treatments 185
Castings and alloys
1, 150, 177, 255, 355, 443
Car planing relationship of automotive vehicles to 486
Cecil, Henry A on Application of Diesel Engine to the Yacht 450
Central engine French 42
Combustion of engines 381
Combustion-chamber form 306
Comparison of devices 90
Commercial car types (E P Warner) 71
Cooling engine jacket for profit 436
Compression ratios of steel disc and cast iron pistons for automobiles (J W Wells) 387
Compression of cooling system weights 128
Compression of cooling 469
Constructional features demanding attention in bearings 29
Corporate assessment to a small production basis specification of 137, 442 479

Crankcase

Adjustment of feed to allow proper functioning 361
Cooling 361
Fuel supply 36
Control for thermostatic valve 361
Heating arrangement of valve 361
Cooling capacity of thermostatic valve (C H Lapsley) 70
Cooling efficiency 147

Cooling Systems

Connection of engine 136
Design 137

Crankcase

Air-cooled engine 311
On the problem of engine lubrication (E P Farnsworth) 364
On the temperature and viscosity of engine lubricants (W J L Haslam) 60
Connection of crankcase and fan 136
Crankcase ventilation 136
Crankcase ventilation and its relation to engine lubrication 110

Cranks

Adjustment of main bearings and crankshaft 257
Alignment 41
Connecting-rod bearing 427
Crankcase 55
Crankcase ventilation 55
Engine 55
Engine lubrication 55
Engine mounting 55
Engine valve 55
Engine valve-gear 55
Engine valve-gear adjustment 55
Engine valve-gear design 55
Engine valve-gear lubrication 55
Engine valve-gear operation 55
Engine valve-gear timing 55
Engine valve-gear troubles 55
Engine valve-gear valve 55
Engine valve-gear valve-seat 55
Engine valve-gear valve-stem 55
Engine valve-gear valve-stem guide 55
Engine valve-gear valve-stem guide lubrication 55
Engine valve-gear valve-stem guide oiling 55
Engine valve-gear valve-stem guide oiling system 55
Engine valve-gear valve-stem guide oiling system lubrication 55
Engine valve-gear valve-stem guide oiling system lubrication system 55
Engine valve-gear valve-stem guide oiling system lubrication system valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve 55
Engine valve-gear valve-stem guide oiling system lubrication system valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear valve-seat valve-stem valve-gear

Radiator capacity and horsepower 30
Reasons for single-eight 257
Reliability of Diesel 491
Rocking couples 487
Rotary-disc valve 422
Rotary-tube valve 422
Rotary valves for internal-combustion 422
Separate-valve difficulties 306
Single-valve internal-combustion design and operation 301
Spark-advance in internal-combustion 73, 111, 226
Supplementary spark-advance tests on a Continental 120
Tendencies in high-speed marine design 168
Total unbalanced forces 487
Valve adjustment and gearing 308
Vibration 417
Equalization of brakes 56
Errors of the V-block method 371
Evaluation of the turbulence factor 173
Evils of crankcase dilution (E F Hallock) 525
Evils of head-lamp dimming and instructions on regulation (R E Carlson) 526
Evolution of industry, science in the 200
Exhaust-heated vaporizer 130
Explosion time of fuel mixtures 113
Exports and imports 295
Exports and imports, our "invisible" 392

F

Factor of safety 299
Factors governing "out-of-roundness" measurement (A H Frauenthal) 370, 435, 484
Factory engineering-staff and its relation to service (J W Lord) 93
Falge, R N, on Importance of Better Automobile Head-Lamps and Proper Adjustment 25, 221, 520
Farmer 408
Farmer, one-crop 472
Favary, E, on Rear Axles for Trucks 151, 234
Federal aid road construction 29
Field of motor trucks 124
Financial situation, France's 440
Finishing piston-ring grooves 407
Fire hazards of automobiles 247
Fisher, J B, on 100 Ton-Miles Per Gallon 139

Flat-Rate System

How engineer can cooperate to make more successful 530
What lessons of value to engineer has developed 528
Forces and motion between wheel and road 171, 248
Ford, F H, on Illumination Diagrams for Showing Head-Lighting Device Performance 333
Forging properties, effect of oxygen upon 103
Foundry production practice 128
Four-wheel brake session at semi-annual meeting 70
Four-wheel braking systems 55

Frames Division, S A E

Activities 503
Report at semi-annual meeting 82
France's financial situation 440
Frauenthal, A H, on Factors Governing "Out-of-Roundness" Measurement 370, 435, 484
Freight, unparalleled volume of traffic 416
French colonial empire 62
Frost, Thomas H, on Photoelastic Method Applied to Rigid-Airship Research 497

Fuel Consumption

In yacht engines 451
Single-valve engine 306
Tests and results 6
Fuel session at semi-annual meeting 73
Fuelizer operation 264

Fuels

Acetone in composite engine 23
Air-temperature and viscosity effects 9
Automobile test 87
Benzol as engine 379
Comments of drivers 90
Consumption tests and results 6
Economic volatility of motor 3, 226
Effect of compression on detonation and detonation control 144
Explosion-time 113
How tested 379
Performance of benzol 379
Summer road-tests 4
Winter road-tests 5
Winter tests show lower mileage with heavy 87, 166, 226
Full-floating axles 155
Functional system of factory management 434
Functionalized time-study methods (Percy S Brown) 133
Fundamentals in engineering (C F Kettering) 427

G

Galloping and front-wheel toe-in 46
Gas distribution in engines 263

Gasoline

Direct determination of dew-points of air mixtures 170
Electric power versus 324
Gear-grinding and tooth-forms 248
Gear-testing machine 405

Gears

Burnished and polished 515
Burnished method 516
Fundamental analysis of noise 514
Grinding favored 515
Hobbed and oil-treated, more accurate 514
Metallurgical considerations in grinding 515
Methods of attacking the noise problem 514
Noise 514
Rigid cutter inspection 515
Spur, grinding and testing 401, 430, 473
Testing machine 405
Upset blanks give uniform tooth-strength 515
Wearing qualities 267
General-purpose farm tractor (C M Eason) 196
German bank funds 420
Grant, R H, address 136
Gravity conveyor for transmission cases 360
Grimes, C P, on Air-Cooled Automotive Engines 125

Grinding

Cam 388
Developments in production, in the automotive industry 387, 431, 475
Gear, favored 515
Metallurgical considerations in gear 515

Grinding Machines

Crankshaft 392
Description of spur gear 402
Indexing 405
Special attachments 389
Special machines 391
Use of wide-face wheel 389
Utilization of the generating principle 404
Griswold, W R, on Packard Single-Eight 257, 485

Group Piece-Work

Adding new men 382
Combination of systems 381
Material supply and costs 383
Number of men required 381
Records 382
Size of group 383
Unit-cost 382
Gruse, W A, on Direct Determination of Dew-Points of Gasoline-Air Mixtures 170
Guillelmon, Marcel, on Renault Mechanical Four-Wheel Braking System 57, 216

H

Hale, J E, on Public's and Car-Builders' Attitude Toward Balloon Tires 461
Hale, J E, on Shoeing a Car with Low-Pressure Air 41, 213
Handling the trimming of bodies 363
Harrison, H P, on Application of Conveyor Equipment to a Small Production Plant 357, 432, 479
Head-lamp glare session at semi-annual meeting 69

Head-Lamps

Areas of equal illumination 337
Automobile regulation 249
Candlepower distribution 336
Car builders' responsibility 527
Constructional features demanding attention 99
Educational campaign 527
Evils of dimming and instructions on regulation 526
Illumination diagrams for showing performance 333
Importance of better automobile and proper adjustment 25, 221, 520
Lens design that eliminates focusing 28
Trend of legislation 526
Underlying principles of good 25
Helium in airships 400
Heron, S D, on Aircraft-Engine Practice as Applied to Air-Cooled Passenger-Car Engines 16
Highway-transportation brains 138

Highways and Roads

Bureau of Public Roads tests 248
Character and use of materials 496
Coefficient of friction for wet concrete higher than dry 522
Construction costs 510
Construction methods in England 493
Economic theory of improvement 495
Engineers discuss program of tests 66
Federal aid construction 29
Finance 496
Land grant colleges cooperate in research 496
Macadam surfacing 493
Maintenance 510
Mechanics of stiff slabs 496
Motion and forces between wheel and 171, 248
Objectives of research 496
Observations on the field in Europe 493
Publication of results of tests will be handled cooperatively 66
Relation of vehicle to 65
Relationship of automotive vehicles to pavements 426
Research an important factor in improvement 495
Research in North Carolina 496
Rubber for quiet zones 493
Structural design 496
To increase safety of traffic 206
Traffic analysis 496
Transportation brains 138
Upkeep at trifling cost 493
Highways Committee, S A E, meeting at semi-annual meeting 65
Horning, H L, on Effect of Compression on Detonation and Detonation Control 144
Hot-spots as control factors 147
How engineer can cooperate to make flat-rate more successful (J W Lord) 530
Human element in production (W F Jameson) 366, 432, 478
Hunt, J H, on Science and Engineering 51
Hydraulic four-wheel brakes for automotive vehicles (Malcolm Loughead) 313

I

Illumination charts show head-lamp performance 333
Illumination diagrams for showing head-lighting device performance (F H Ford) 333
Importance of better automobile head-lamps and proper adjustment (R N Falge and W C Brown) 25, 221, 520
Importance of right thinking 366

Imports

Exports and 295
Our "invisible" exports and 392
Impurities in storage-battery electrolytes 36
Indicator-reading correction 372
Inertia the great obstacle 368
Influence of scale on metals 410
Information service 284
Internal-gear drives 152, 160
Ionization and mass measurements 468

Iron and Steel Division, S A E

Activities 104, 105, 344, 508
Personnel 65, 408, 509
Report at semi-annual meeting 82
Irrigation development 472

J

James, William S, on Decelerometer for Testing Automobile Brakes 499
Jameson, W F, on Human Element in Production 366, 432, 478

K

Kennedy, William P, on Trolley Buses and Flexible Vehicles for Street Railway Service 179, 322
Knight, O A, on Developments in Production Grinding in the Automotive Industry 387, 431, 475
Knuckle-axis, moment about 270

L

Laboratory tests 6
Larson, J Lyman, on Tractor and Plow Usage in the First Breaking of Peat Land 285
LaSchum, E E, on Engineering Brains in Fleet Operation 276
Lee, Stephen M, on Economic Motor-Fuel Volatility 3, 226
Lemon, H B, on Nature of Matter 466
Lens design that eliminates focusing 28

Meetings

June

Motor Trucks

Analysis of emergency calls 278
Carrier inspector necessary 282
Chain drive 151, 166
Combined engineering and business efforts to cut operation 279
Coordination of railroad and transportation 122
Distribution of maintenance costs 277
Double-reduction drive 163
Final power equipment 278
Engineering losses in fleet operation 276
Field of 124
Fleet operation costs 280
Full-floating axles 155
Future practice 281
Internal-gear drive 152, 160
Maintenance difficulties 281
Necessity for engineering knowledge 277
Rational design 393
Rear axles for 151
Semi-floating axles 153
Worm drive 152, 156
Motor-vehicle wheel-alignment (John F Dodge) 453

Motor Vehicles

Bevel gear and chain drives 151
Body and chassis requirements 187
Critical study of modern steering systems 205
Dual power bus equipment 183
Engineer must be future link 516
Equipment and methods of tests 141
Fleet owners study transportation costs 517
Flexible equipment requirements 187
Former relation of maker to user discussed 516
Hydraulic four-wheel brakes for 313
Independent buses with electric transmission 184
Maintenance an engineering problem 517
One hundred ton-miles per gallon 139
Relation of automotive manufacturer to 516
Relation to road 65
Relationship to city planning traffic routing and pavements 426
Semi-trailers 324
Transportation is the commodity sold 38
Types of buses for street-railway service and 179, 322
War on the locomotive 46
Wheel alignment 453
Multiple-spindle machine tools (E P Blanchard) 430

N

National Accountants' Association meeting 399
Nature of matter (H B Lemon) 466
Nebraska tractor-test analysis (Oscar W Sjogren) 197
Non-skid pads on balloon tires 426

Nomenclature

Body 437
Tire size 49

Nomenclature Division, S A E

Report at semi-annual meeting 82
Recommended recommendation 84
Non-Ferrous Metals Division, S A E activities 418
Non-precision affiliation with Sections 498

O

Obsolescence to flat-rate [illegible] 61
Observations on the automobile and highway transport in Europe 492
Officers nominated for 1924 62
Office of Public Roads, motor transport [illegible] 5
Oil [illegible] filter 47
Oldsmobile [illegible] 47
One hundred ton-miles per gallon (J B Entwistle) 139
Open-hearth [illegible] furnace 119
Oscillating [illegible] 47, 48
Oscillating [illegible] 47, 48
Overhead [illegible] 47, 48
Overhead [illegible] 47, 48
Overhead

Objectives of highway 496
On tires 495
Photoelastic method applied to rigid-airship 497
Research Department, S A E, information service 284
Resiliency and fatigue in wheels 210
Resistance of oil-films in high-speed bearings, thickness and 101
Resistance, analysis for mixed 270

Roads and Highways

Bureau of Public Roads tests 248
Character and use of materials 496
Coefficient of friction for wet concrete higher than dry 522
Construction costs 510
Construction methods in England 493
Economic theory of improvement 495
Federal aid construction 29
Finance 496
Land grant colleges cooperate in research 496
Macadam surfacing 493
Maintenance 510
Mechanics of stiff slabs 496
Motion and forces between wheel and 171, 248
Objectives of research 496
Observations on the field in Europe 493
Publication of results of tests will be handled cooperatively 66
Relation of vehicle to 65
Relationship of automotive vehicles to pavements 426
Research an important factor in improvement 495
Research in North Carolina 496
Rubber for quiet zones 493
S A E engineers discuss program of tests 66
Structural design 496
To increase safety of traffic 206
Traffic analysis 496
Transportation brains 138
Upkeep at trifling cost 493
Rolling-resistance, wheel forces and 269
Rotary disc valve engine (O D Heavenrich) 422
Rotary valves for internal-combustion engines (Eugene Bournonville) 422
Rutherford idea 469

S

S A E

Council meeting:
June 65
October 408
Engineers discuss program of highway tests 66
1924 annual meeting announced 177
Officers nominated for 1924 62
Production meeting announced 347
Report of production meeting 429
St. Louis Air Meeting 399

Science

In the evolution of industry 200
Predictions 54
Science and engineering (J H Hunt) 51
Scientific working conditions 51

Scleroscope

Brinell hardness compared with 414
Condition of the hammer diamond 411
Curved surface, effect of 413
Extreme under-weight samples 412
Hardness effect of, on mass 413
How test-specimens are held 414
Inert and over-weight masses 412
Lateral vibrations, effect of 410
Mass of the test-specimen, effect of 411
Plumbness of 409
Standardization of methods of applying 409, 483
Surface smoothness of the test-specimen 410
Testing near specimen edges 413
Thickness of the test-specimen 413

Screw Threads Division, S A E

Activities 104, 418
Personnel 408

Sections, S A E

Formation of Milwaukee begun 426
Luncheon at semi-annual meeting 68
Non-member affiliation 408
Sections Committee, S A E, luncheon at semi-annual meeting 68
Selling service (W L Wise) 528

Semi-Annual Meeting, S A E

Air-cushion tire session 66
Business session 64
Four-wheel brake session 70
Fuel session 73
Head-lamp glare session 69
Report 63
Sports 68
Standards Committee meeting 65
Semi-floating axles 153

Service

Causes of trouble not properly diagnosed 524
Cooperation in the solution of problems 384
Designers must recognize requirements 523
Electrical problems as encountered in the field 529
Elements of, facilities 384
Engineer's viewpoint of 60
Establishment of associations 524
Factory engineering-staff and its relation to 93
London General Omnibus plant 493
Manager 38
Objections to flat-rate charges 61
Platform of National Automobile Chamber of Commerce division 524
Providing the engineer with data to improve design 527
Sales competition will raise standards 524
Selling 528
What lessons of value to engineer has flat-rate system developed 528
What part engineer can play in reducing repair costs 525
Service division of National Automobile Chamber of Commerce platform 524
Service from the engineer's viewpoint (B B Bachman) 60
Service meeting, S A E, Dayton 523

Servo-Brakes

Adjustment 58
Description 58
Principles of 58
SHANLEY, JAMES J. ON AUTOMOBILE HEAD-LAMP REGULATION 249
Shoeing a car with low-pressure air (J E Hale) 41, 213

Shock-Absorbers

An essential addition 426
Should have neutral zone 521
Shock-absorbing devices 446
SHORE, A F, ON STANDARDIZATION OF METHODS OF APPLYING THE SCLEROSCOPE 409, 435, 483
Side-sway of automobiles 46
Silver, production and use of 275
Simplification 386
Single-valve internal-combustion engine design and operation (R Abell) 301
Six-wheel motorbuses 331
SJOGREN, OSCAR W, ON NEBRASKA TRACTOR-TEST ANALYSIS 197
Smoothness of test-specimen in scleroscope 410
Social interests, unity of 438
Some notes on brake design and construction (H M Crane) 395, 421
Spark-advance in internal-combustion engines (G B Upton) 111, 226

Spark-Advance

Cornell University tests 119
Correlation of optimum, and explosion-time 116
Evaluation of turbulence factor 173
In internal-combustion engines 73, 111
Supplementary tests 120
Special machines, standard versus 434

Specifications

Carbureter 140
Packard single-eight 257

Spokes

Breakage 202
Design 202
Triple system of 203
Spring-movement and vibration study of cars in action (T J Litle, Jr) 445

Springs

Measuring and recording devices 445
Study of 446, 521
Spur-gear grinding and testing (A J and C L Ott) 401, 430, 473
Standard versus special machines (R E Flanders) 434

Standardization

Activities in motorbus 378
Interchangeable motorbus parts 494
Methods of applying the scleroscope 409
Saving in dollars and cents 59
Standardization of methods of applying the scleroscope (A F Shore) 409, 435, 483
Standardization saving in dollars and cents 59
Standards adopted by letter ballot 246

Standards Committee, S A E

Attendance at semi-annual meeting 85
Meeting at annual meeting 531
Meeting at semi-annual meeting 65
Report at semi-annual meeting 79
Staten Island trackless trolley 326
Stationary-Engine Division, S A E, report at semi-annual meeting 83
Stanton machine 40
Steam cooling-system 142

Steels

Cutting tests of high-speed 59
For disc wheels 211

Steering

Center-point 489
Comfortable 272
Critical study of modern automotive-vehicle systems 205
Derivation of formula for turning moment about the pivot 488
Fundamental requirements 268
Steering ability and reinforcement 57
Steering-arm mounting 56
Steering-gear efficiency 273
STONEY, DR GERALD, ON THICKNESS AND RESISTANCE OF OIL-FILMS IN HIGH SPEED BEARINGS 101
Storage-Battery Division, S A E, activities 104
Storage-battery vehicle 325
Storage-batteries, impurities in electrolytes 36

Street Railway

Automotive cooperation with 180
Body and chassis requirements 185
Changing conditions 179
Differences of engineering practice 180
Dual-power bus-equipment 183
Flexible-equipment requirements 187
Independent buses with electric transmission 184
Influences tending toward flexible equipment 179
National practices 182
Profit-earning vehicle needed 325
Prospective business 187
Transportation permanency 187
Trolley bus as one solution 181
Trolley buses and flexible vehicles 179, 322
Street-railway service, trolley buses and flexible vehicles for 179
Summer road-tests 4

T

Tendencies in high-speed marine-engine design (J G Vincent) 168
Terminal transportation 123
Terminal transportation in Canada 123
Testing materials for automotive parts (R J Allen) 39
Testing of materials and its effect on engineering (G B Upton) 296

Tests

Automobile 446
Benzol as engine fuel 379
Brinell and scleroscope-hardness comparisons 414
Bureau of Public Roads highway 248
Companies making automobile 88
Crankcase-dilution 10
Crankcase-dilution, conclusions drawn from 14
Crankcase-dilution, results of 12
Curved surfaces, effect of, in scleroscope 413
Cutting, of high-speed steel 59
Deceleration, of automobiles 495
Decelerometer for automobile brakes 499
Dilution, procedure 11
Dynamic, of automobile parts 39
Engineers lead in Army intelligence 86
Equipment and methods for motor vehicle 141
Extreme under-weight samples in scleroscope 412
Fuel-consumption, and results 6
Hardness, effect of, on mass in scleroscope 413
High-speed steel cutting 59
How specimens are held in scleroscope 414
Inert and over-weight masses in scleroscope 412
Influence of scale on metals in scleroscope readings 410
Instruments for toe-in 456
Laboratory, of fuel 6
Machine for gear 405

Tires

Blow-outs
Rear wheel, inflation
Balloon
Motion and forces between road and
Noise
Resiliency and fatigue
Wire

Traffic and Transportation

Bridges, loads for
Capacity of highways
Congestion, relief from
Electric railways
Motor-truck
Parking
Passenger cars
Public utilities
Railroads
Regulation
Roads
Safety
Speed
Taxation
Traffic control, relationship of automotive vehicles to
Transportation
Trolley bus as one solution
Unparalleled volume of freight

Transmission Division, S A E

Activities 346, 503, 505
Personnel 408
Transmission design 266
Transportation 374, 439
Transportation is the commodity sold 38
Trap cars 124
Trimming of bodies, handling the 363
Trolley bus 325
Trolley bus as one solution 181
Trolley buses and flexible vehicles for street-railway service (William P Kennedy) 179, 322
Truck Division, S A E, report at semi-annual meeting 83
Trucks, rear axles for 151, 234
Turbulence 117, 148
Turbulence, evaluation of factor 173
Two kinds of engineering (F E Moskovics) 37
Types of construction of brakes 56
Types of out-of-roundness 370

U

Unity of social interests 438
Unparalleled volume of freight traffic 416
Upton, C B, on Spark-Advance in Internal Combustion Engines 111, 226
Upton, C B, on Testing Materials and Its Effect on Engineering 296
Use of acetone in composite engine-fuels (R F Remler) 23
Use of precision bearings on engine crankshafts (L W Chadwick) 124

V

V-Block

Elliptical objects in a 372
Errors of the method 371
Valence 467
Value of auto-suggestion 368
Valve-gear and cylinder 264

Valves

Adjustment and gearing 308
Advantages claimed for disc 422
Camshaft poppet and distributor 123
Definitions of separate 306
Exhaust cutting mechanism 308
Investigation for cylinder 422
Inquiry for internal-combustion engines 421
Poppet, disc, for internal-combustion engines 422
Valves, location, setting of 466

Vibrations

Effect of crowd on microscope 446
Engine 447
Engine movement and study of cure in mills 445
Tests of automobiles 448
Vincent, J G, on Forward Stagger Engine 257, 485
Vincent, J G, on Tendencies in High-Speed Marine Engine Design 168
Viscosity, air temperature and fuel effects 9

W

Wage-incentive system (Eugene Boureton) 380, 432, 480
War on the locomotive 40
Warner, John A C, on Winter Tests Show Lower Mileage with Heavy Fuels 87, 166, 226
Wentworth, R S, on Motor-Truck Radiator Design 393
What can engineer do to help the public (T A Wachter) 530
What lessons of value to the engineer has that rate system developed (D T Hastings) 528
What "ought" to be done 86
What part the engineer can play in reducing repair costs by eliminating the need for costly tools (W A Francis) 525
Wheat acreage 406
Wheat, price of 498

Wheel-Alignment

Axle tilt and 457
Correct 455
Front 454
Motor vehicle 453

Wheels

Adjustment of parts 59
Amount of camber 456
Amount of toe-in 455
Axle-tilt and alignment 457
Balloon tires interfere with housings 522
Braking systems on four 55
Camber 454
Comparative merits of steel disc and wood, for automobiles 207
Correct alignment 453
Disc and wood, comparisons 208
Disc, tire inflation 208
Driving parts 204
Energy for acceleration 210
Essential technical features 209
Finish 211
Five or four sets 208
Forces and rolling resistance 269
Forces for locked 270
Front, alignment 454
Galloping and toe-in on front 46
Mechanical braking on four as a present automotive necessity 55, 216
Method employed to determine toe-in 455
Mileage, tire changes and get-away 204
Motion and forces between road and 171, 248
Motor-vehicle alignment 453
Noise 210
Other factors affecting toe-in 455
Resiliency and fatigue 210
Special equipment for tractors 291
Spoke breakage 202
Spoke design 202
Steel for disc 211
Testing instruments 456
Triple-spoke system 203
Trueness of 456
Wabble 457
Wire 201
White, J W, on Comparative Merits of Steel Disc and Wood Wheels for Automobiles 207
Winter road-tests 5
Winter tests show lower mileage with heavy fuels (Dr H C Dickinson and John A C Warner) 87, 166, 226
Wire wheels (C W W Davison) 201
Workingman, American 437
Worm drive axle 152, 156

Y

Yachts

Cost of engines 450
Fuel consumption 451
Present Diesel installations 451
Yachting field, application of Diesel engine to 450
Yocom, Alvin M, on Mechanical Braking on Four Wheels as a Present Automotive Necessity 55, 216

KERITE
A product of over fifty years distinguished service in the most important electrical fields, possessing inherent characteristics which make it pre-eminently desirable for
High Tension Automotive Ignition
DAYS KERITE
KERITE
INSULATED WIRE & CABLE
COMPANY
NEW YORK CHICAGO
KERITE
COMPANY

"NORMA"
PRECISION
BALL BEARINGS

The one criterion of success is a record of satisfactory service—whether in the car or truck as a whole, or in one of its parts.

One failure may wipe out a record for reliability and dependableness that has been years in the making.

Year after year, "NORMA" equipped magnetos and lighting generators hold their recognized leadership — solely because of their consistently superior performance.

Service records prove that magnetos and lighting generators with "NORMA" Precision Bearings, run more quietly, last longer.

A booklet will be sent on request. And our engineers will welcome an opportunity to work with yours.

THE NORMA COMPANY OF AMERICA
Anable Avenue
Long Island City New York
BALL, ROLLER AND THRUST BEARINGS

Personal Notes of the Members

Items regarding changes in business connections, promotions, etc., are desired from the membership for insertion in these columns. This will enable members to keep their friends informed of their whereabouts and will also assist in keeping the records of the Society up to date.

Paul C. Ackerman has accepted a position as draftsman of the Doble Steam Motors Corporation, San Francisco. Previous to this connection he attended the Michigan State Auto School, Detroit.

George B. Allen, who until recently was chief engineer for the Liberty Motor Car Co., Detroit, is now connected with the engineering department of Dodge Bros., also of Detroit.

John H. Allen has been made general manager of the Eisemann Magneto Corporation, Brooklyn, N. Y., succeeding Charles Ethan Davis, resigned. Mr. Allen has been associated with the Eisemann organization for several years in the capacity of works manager and assistant general manager.

J. S. Anderson, who was formerly chief engineer for the Phelps Light & Power Co., Rock Island, Ill., has become affiliated with the Checker Cab Mfg. Corporation, Kalamazoo, Mich.

A. Caryl Bigelow is no longer president and general manager of the United Motor Car Co., Trenton, N. J., but has been made vice-president and general manager of the Wills Sainte Claire Co. of New York, New York City.

George C. Brainard has become affiliated with the General Fireproofing Co., Youngstown, Ohio. Previous to this he was vice-president of the Hydraulic Steel Co., Cleveland.

W. J. Bryan resigned recently from the Budd Wheel Co., Philadelphia, where he was sales manager for the last 4 years, to become associated in a similar capacity with the Detroit office of the Heintz Mfg. Co., also of Philadelphia.

Walter P. Burn has been appointed Pacific coast manager for the Outdoor Advertising Agency of America, New York City. His previous business connection was with the Transcontinental Oil Co., Pittsburgh, as sales promotion and advertising manager.

Henri G. Chatain, who was formerly engineer in connection with gas-electric motor cars for the General Electric Co., Erie, Pa., is now affiliated with the engineering department of the Hammermill Paper Co., also of Erie.

Reginald Clark recently became associated with the Spicer Mfg. Co., Plainfield, N. J. He was prior to that time factory manager for the Western Drop Forge Co., Marion, Ind.

Harry L. Coffey has accepted a position with the American Motors Corporation, Plainfield, N. J.

H. C. Colburn has become chief engineer of the Colburn Radio Laboratories, San Leandro, Cal. He was formerly radio engineer for the Magnavox Co., Oakland, Cal.

(Continued on p. 4)

DIXON'S 677

Dixon's 677 may be obtained in steel drums with pump, providing a quick, clean means of lubricating gear-boxes. A necessity in every garage and service station. Write for quotation.

It has been ascertained by tests that Dixon's Gear Lubricant No. 677 gives as good service at freezing temperatures (winter conditions) as at higher temperatures (summer conditions).

When it is taken into consideration that an automotive transmission and differential has to meet this wide temperature difference, and especially when lubricated with the average gear oil that congeals at low temperatures, making gear shifting extremely difficult, the actual power losses are easily apparent. Dixon's 677 prevents such losses.

Write for Booklet 95-G

JOSEPH DIXON CRUCIBLE COMPANY

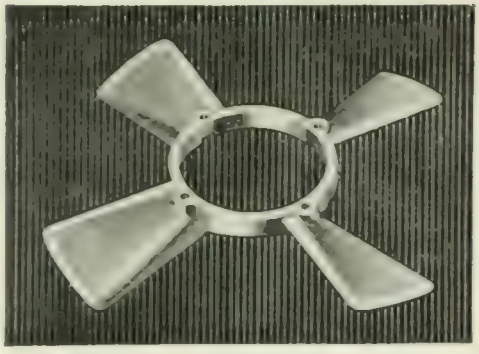
Jersey City, N. J. *Established 1827*

MAKERS OF QUALITY LUBRICANTS

DOEHLER

The World's Largest Producer of

DIE-CASTINGS



The finish to be given die-cast parts in various metal alloys—plating, enamel, etc.—sometimes involves problems new to the die-casting user.

Daily contact with every phase of industry using die-castings, and constant research along chemical and metallurgical lines, enable Doehler engineers to be of material assistance in special problems like this.

The Doehler Company willingly places its experience and resources at the disposal of its customers, in using Doehler Die-Castings for the best results.

DOEHLER DIE CASTING CO.
BROOKLYN. N.Y.
TOLEDO. OHIO.

PERSONAL NOTES OF THE MEMBERS

Continued

Lewis H. Davis has been appointed chief inspector for the Stutz Motor Car Co., Inc., Indianapolis. Until recently he attended Purdue University, Lafayette, Ind.

Edward Dixon, who was formerly chief engineer for the Checker Cab Mfg. Co., Chicago, has been elected president of the Big 4 Auto Co., also of Chicago.

O. M. Donaldson, who for a number of years was Cleveland district manager for the Briggs & Stratton Co., Milwaukee, and since October, 1922 was in charge of motor sales for the Allis-Chalmers Mfg. Co., Chicago, has been appointed director of manufacturers sales for Outlook, Cleveland.

Albert H. Doolittle has become affiliated with the Philbrin Corporation, Kennett Square, Pa., as sales manager.

Clarence A. Earl has been made president of National Motors, Inc., Chicago.

George F. Fisher has accepted a position with the Continental Mexican Rubber Co., New York City.

G. E. Franquist has severed his connection as chief engineer for James Cunningham, Son & Co., Rochester, N. Y. His plans for the future have not been announced.

L. O. Haskins, who was formerly president of the Water Baby Mfg. Co., Detroit, has been appointed director of sales of the Ohio Trent Coal, Coke & Amalgam Co., Toledo.

Fred A. Hoyt has accepted a position as engineer for the Western Electric Co., New York City.

Major Mark L. Ireland has been assigned to the 79th Division, Organized Reserves, at Schuylkill Arsenal, Philadelphia. Previous to this he was detailed for 2 years at the Massachusetts Institute of Technology, Cambridge, and for 1 year at the University of Michigan, Ann Arbor, to study the interrelationship of highway, railway and waterway transport.

C. M. Johnson has accepted a position as salesman for the Washington Hardware Co., Tacoma, Wash.

I. L. Johnson, who was formerly machinist for the Minneapolis Steel & Machinery Co., Minneapolis, is now affiliated with Fairbanks, Morse & Co., St. Paul, Minn.

Hugh I. Jones has severed his connection with the Willys Morrow Co., Elmira, N. Y., where he was assistant metallurgist. His plans for the future have not been announced.

Alexander W. Keller has become associated with Edward Smith & Co., Long Island City, N. Y.

E. W. Kelley, who was previously draftsman for the Fulton Iron Works, St. Louis, has accepted a position with the Weaver Mfg. Co., Springfield, Ill.

Albert E. Koeckert, who was until recently manager for the Phoenix Engineering Co., Cleveland, is now associated with the Mechanical Rubber Co., also of Cleveland.

Roland M. Kohr has been made chemist for the Grasselli Chemical Co., Clarksburg, W. Va. Previous to this he held a similar position with the National Refining Co., Findlay, Ohio.

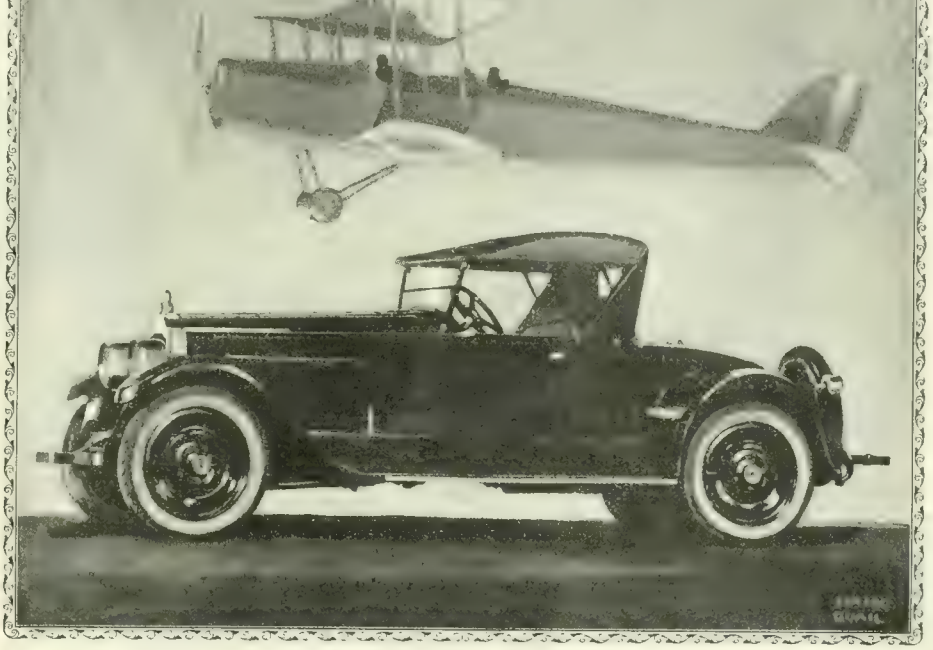
Henry Krebs, who was formerly in the turbine drafting department of the General Electric Co., Lynn, Mass., has joined the engineering department of the Packard Motor Car Co., Detroit.

(*Continued on p. 6*)

SINGLE-EIGHT

A New Production by

PACKARD



The striking thing about the Single-Eight is that it does the things which are vital, in a more positive, effective way, than they have ever been done before.

...king contributions to ...other motoring, ...ements, but very definite qualities quickly discernible.

It is not just a generalization but a fact, that in comfort, acceleration, flexibility, brake-action, steering and ease of control, the Single-Eight has gone far beyond previous practice.

The instant and enthusiastic acceptance of these facts renders it certain that the Single-Eight will dominate its own particular field just as unmistakably as does its companion car—the Packard Single-Six.

...ine Distinguished Body Types, Open and Enclosed, at Prices Ranging from $... to $...—at Detroit
Packard Single-Six Furnished in Eleven Popular Body Types, Open and Enclosed

SRB Bearings in Packard Motor Cars are located as follows:

Single-Six
Clutch throwout
Transmission mainshaft rear
Rear axle wheels

Single-Eight
Clutch throwout
Transmission mainshaft rear
Rear wheels
Steering column

SRB

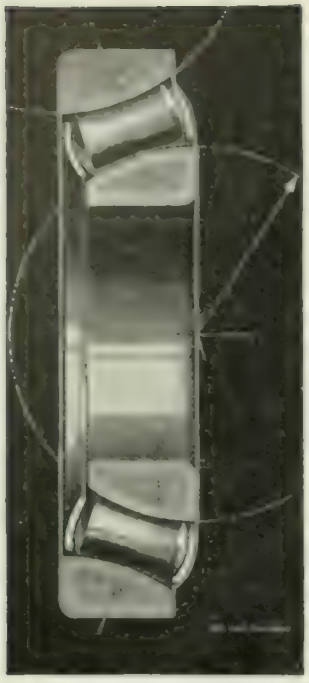
THE Packard Motor Car Company has long relied upon this Organization as a source of supply for Annular Ball Bearings, as have a majority of the larger independent automobile, truck and tractor manufacturers.

SRB Annular Ball Bearings have built up an enviable reputation for accurate workmanship—long life—correct design—and quiet frictionless operation and are, therefore, a logical part of the mechanism of the finer types of American automotive manufacture.

STANDARD STEEL AND BEARINGS INCORPORATED

PLAINVILLE CONNECTICUT

SRB Bearings are serviced by the branches of the Standard Sales and Service Co., throughout the United States


(Pat. and Pat. Pending)

STEEL

Cups, cones and rollers of SHAFER ROLLER BEARINGS are made of ALLOY STEEL. This steel is made to our special analysis by one of the foremost exclusive alloy steel mills of America.

SHAFER BEARING CORP.

6501-99 West Grand Ave.

Chicago, U. S. A.

SHAFER
Self-Aligning ROLLER BEARING

PERSONAL NOTES OF THE MEMBERS

Continued

Joseph B. Lindecker has severed his connection with the Willys-Overland Co., Toledo, where he was layout draftsman in charge of the patent drafting department. No announcement has been made of his future plans.

Frank J. Lucas, who until recently was chief engineer for the Hamilton Beach Mfg. Co., Racine, Wis., has become mechanical engineer in charge of methods development at the Hawthorne Works of the Western Electric Co., Cicero, Ill.

E. T. Mathewson resigned on Nov. 1 as district manager of the S K F Industries, Inc., Buffalo, to devote his entire time to the development of the products of the Nichols & Wright Motor Co., Buffalo, of which he has been president for the past 5 years.

A. H. Midgley, who was formerly technical director of Scholey & Co., Ltd., London, S. W., England, has organized the Midgley Car Lighting Co., Ltd., also in London.

Clifford A. Miller has accepted a position as assistant chief draftsman in the engineering department of the White Motor Co., Cleveland. He was previously engineer and designer for Weaver & Kemble, also of Cleveland.

G. Reynolds Miller has severed his connection with the Daniels Motor Co., Reading, Pa., where he was general purchasing agent. His plans for the future have not been announced.

Robert I. Miner, who was previously tool engineer for the Cadillac Motor Car Co., Detroit, has been made assistant chief engineer for the Bossert Corporation, Utica, N. Y.

Herbert N. Nigg has been appointed general manager of the Frost Gear & Forge Co., Jackson, Mich. He was formerly vice-president and general manager of the Detroit Bevel Gear Co., Detroit.

John W. Peterson has severed his connection as factory manager in the wheel division of the Detroit Pressed Steel Co., Detroit. His plans for the future have not been announced.

A. G. Prosperi, who was formerly president of the Oakland Sales Co., Tampa, Fla., has become associated with Harvey Ringler Motor Sales, Philadelphia.

P. W. Rhame has been made superintendent of inspection for the A. C. Spark Plug Co., Flint, Mich. He was until recently instructor in the University of Minnesota, Minneapolis.

Walter C. Robbins, who was formerly connected in an engineering capacity with the Stevens-Duryea Co., Chicopee Falls, Mass., and was also chief engineer for the Curtiss Aeroplane Co., Buffalo, has been appointed general manager of the International Metal Hose Co., Inc., Cleveland.

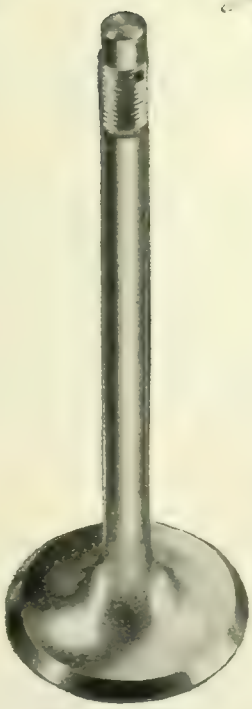
O. J. Rohde has been appointed general manager of the Torrington Co. of Delaware, New York City. His previous business connection was with the Wire Wheel Co. of America, Detroit, in a similar capacity.

Paul H. Schweitzer is now automotive designer for the Yellow Coach Mfg. Co., Chicago. Prior to this he was mechanical engineer and tool designer for the Oakland Motor Car Co., Pontiac, Mich.

Ralph H. Sherry, formerly metallurgical engineer for General Motors Corporation, and later for the Willys Corporation, Elizabeth, N. J., has become associated with the International Harvester Co., Chicago, as chief metallurgist.

(Concluded on p. 8)

Champions!



THOMPSON Silcrome Valves were in the 500 H. P. Curtiss D-12 engine that won the international speed races at St. Louis, averaging 243 miles an hour for 200 kilometers. They are also standard equipment in the Wright motors which set the new 300-hour full-throttle endurance standard now employed by the United States government. Thus designers of finest aeronautical motors confirm the judgment of leading automobile engineers who have specified Thompson Silcrome Valves because they are practically indestructible.

Let us prove, in your own test engines, the ruggedness of this moderately priced valve which hottest motors cannot destroy.

—built by a "trail-breaker of industry"

THE STEEL PRODUCTS COMPANY

Also manufacturers of king bolts, shackle bolts, tie rod bolts, drag links, starting cranks, and brake rod assemblies

Main Plant
CLEVELAND

Michigan Plant
DETROIT

THOMPSON SILCROME VALVES

First class
TOOLS
go with
first class
CARS

CRESCENT WRENCHES
help to solve the
"accessibility problem"

MAKING the working parts of car or truck easily accessible for overhauling, adjustment and repair is something that concerns every car manufacturer.

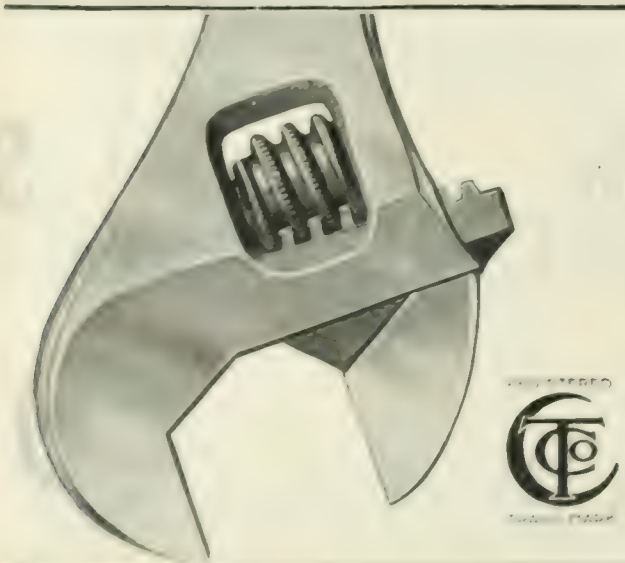
The special design of Crescent Wrenches makes them effective in places where other wrenches are useless.

Crescent sales figures show that car owners the country over prefer Crescent Tools. And in these days of keen competition it is good business to give them what they want as standard equipment.

The Crescent line includes Crescent [illegible], Crescent pliers, and Crescent T-type screwdrivers.

CRESCENT TOOL CO., JAMESTOWN, N.Y.

"The CRESCENT WRENCH People"



PERSONAL NOTES OF THE MEMBERS

Concluded

George W. Sower has joined the engineering department of the Jeffrey Mfg. Co., Columbus, Ohio. He was, until recently, draftsman in connection with aircraft and power-plant design and installation for the Glenn L. Martin Co., Cleveland.

Horace N. Stevenson, who was previously assistant experimental engineer for the Mercer Motors Co., Trenton, N. J., has accepted a position as salesman for the Norman P. Druck Motor Co., also of Trenton.

Frank E. Storey has become chassis designer and layout man for the Hupp Motor Corporation, Detroit. He was formerly layout man for the Maxwell Motor Corporation, also of Detroit.

Foster E. Sturtevant, who was, until recently, chief inspector for the Ward Motor Vehicle Co., Mount Vernon, N. Y., has accepted a position as mechanical engineer with the Bijur Lubricating Corporation, New York City.

Clinton L. Stutter has accepted a position as toolmaker for J. Morrison Gilmour, New York City. He was formerly machinist for the White Truck Co., Long Island City, N. Y.

John Swinscoe has been made manufacturing engineer for the Olds Motor Works, Lansing, Mich. His previous business connections were with the factory organization division central office of the General Motors Corporation, Detroit.

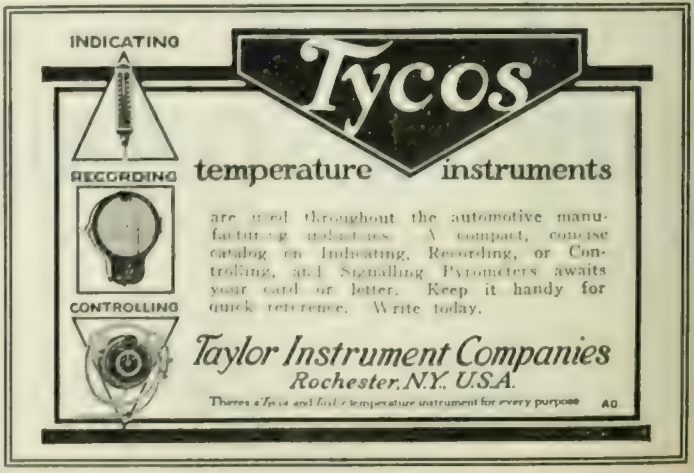
Raymond E. Tetens, who, until recently, was assistant chief engineer for Earl Motors, Inc., Jackson, Mich., has accepted a position as draftsman with the Reo Motor Co., Lansing, Mich.

W. R. Vogeler has become associated with the General Motors Export Co., New York City, and will act in the capacity of field representative for the Central European countries, with headquarters in Copenhagen, Denmark. He was formerly export manager in Weisbaden, Germany, for the King Motor Car Co., and general manager and secretary of the King Car Corporation, New York City.

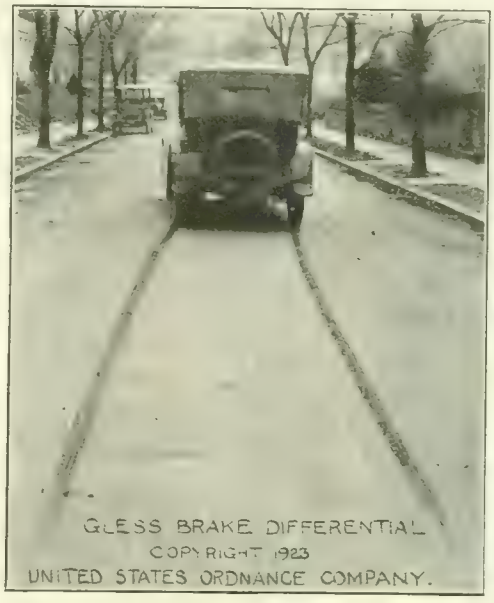
Ewald G. Wahlborg has accepted a position as body draftsman for the Chalmers plant of the Maxwell Motor Corporation, Detroit. Previous to this he was layout designer for Zeder-Skelton-Breer Engineering Co., Newark, N. J.

R. C. Wilson has become affiliated with the Fergus Motors of America, Inc., Newark, N. J.

Chase W. Wolfe, who was formerly manager having charge of manufacturer's sales for the Federal Rubber Co., Cudahy, Wis., is now associated with the Century Rubber Works, Chicago.


INDICATING
Tycos
RECORDING
temperature instruments
are used throughout the automotive manufacturing industries. A compact, concise catalog on Indicating, Recording, or Controlling, and Signalling Pyrometers awaits your card or letter. Keep it handy for quick reference. Write today.
CONTROLLING
Taylor Instrument Companies
Rochester, N.Y., U.S.A.
There's a Tycos and Taylor temperature instrument for every purpose
A0

FRONT BRAKES REAR



Mr. Manufacturer:

You will admit that the force generated by the right and left brakes in stopping a car should be the same.

But

Do you know that equalization of brake forces cannot be effected by any device entirely included in the brake setting mechanism, or in any mechanism which both sets the brake and anchors it against rotation?

Do you know that this statement is susceptible of mathematical proof and that it has been proven?

Do you know that the co-efficient of friction of your brakes can change from day to day and from minute to minute?

And that "What can happen will happen"?

Then you will admit that equalization of brake pressure does not equalize the brake force.

The Gless Brake Differential

DOES equalize the brake force by varying the brake pressure to overcome the variations in the co-efficient of friction.

With it you can duplicate the test shown in the illustration and you can do it every day, and every hour or minute of the day, through rain, snow and mud.

You will not require chains to prevent skidding, and you will not be told to "get a horse" when one wheel spins around in the mud.

With it your external band brakes become 100% efficient.

THE GLESS BRAKE DIFFERENTIAL is neither an accessory nor an experiment. It constitutes a part of the brake mechanism, and has been adapted to various types of brakes.

Efficiency and durability proven by nearly three years of exhaustive tests.

For drawings and specifications write to

UNITED STATES ORDNANCE COMPANY

4612 Woodward Ave., Detroit, Michigan **719 15th Street, Washington, D. C.**

Why Kelly Kats dominate the truck tire field

Kelly Kats are massive single-cushion tires especially designed to give maximum traction, resiliency and mileage on trucks of heavy and medium capacity.

Kelly Kats are able to get traction without chains on almost any kind or condition of road.

Kelly Kats can stand as much, if not more, punishment than solid rubber tires, yet they are far more resilient.

Kelly Kats deliver mileage which makes them economical.

It is because Kelly Kats possess all these qualities that they have steadily grown in popularity until they are now used on hundreds of fleets and thousands of single trucks in all parts of the country and in practically every industry.

There are no Caterpillar tires but Kelly Kats

KELLY-SPRINGFIELD TIRE CO.
250 West 57th Street, N. Y.

Notes and Reviews

In this column are given brief items regarding technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

NEW SLIDING CHANGE-SPEED GEARSETS ANNOUNCED IN EUROPE. Published in *Automotive Industries*, Oct. 25, 1923, p. 830.

This is an account of two new European devices, the Lavaud automatic transmission and the Constantinesco torque converter.

The Lavaud transmission is said to abolish the ordinary change-speed mechanism, the gear-ratio being automatically changed in accordance with changes in the resistance encountered in the rear wheels. In connection with a diagram, its operation is rather fully explained, following a paragraph in which the working of the device is described thus:

> By the Lavaud transmission the continuous rotary motion of the engine crankshaft is transformed into a reciprocating motion of connecting rods whose length of stroke is automatically varied by the traction resistance in inverse proportion to that resistance. This reciprocating motion is again transformed into a continuous rotary motion by ball ratchets.

In the Constantinesco torque converter as in the Lavaud transmission, the distinctive features are infinite variability and automatic variation. The illustration from which the explanation of the Constantinesco device is made is purely diagrammatic, and its exposition is less complete than is that of the mechanism just described. The inventor, it is stated, has called attention to the fact that his gear is a mechanical equivalent of an alternating-current electric circuit containing resistance and inductance in parallel. This similarity is illustrated by two diagrams. Some comment on the new devices is appended at the end of the article.

ACCURATE MANUFACTURE OF AUTOMOBILE GEARS. By A. B. Bassoff. Published in *Machinery*, November, 1923, p. 209.

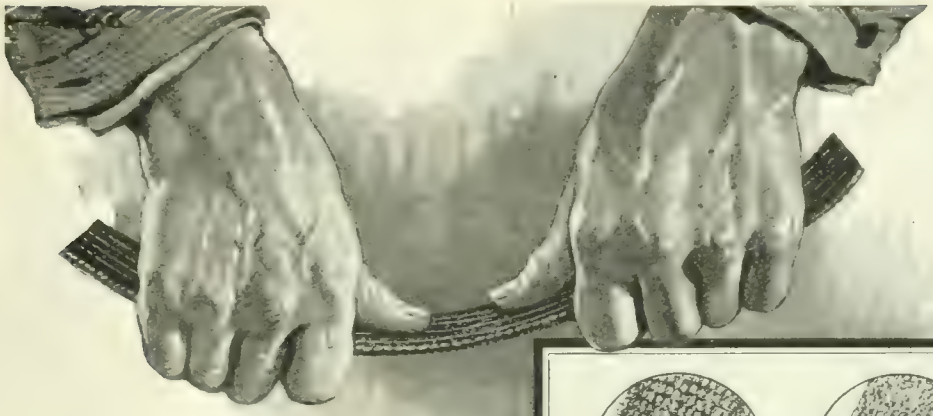
The author outlines the various steps in the manufacturing process adopted in one automobile plant in an endeavor to eliminate imperfections in automobile timing and transmission gears and describes in detail the special machines employed. Four diagrams illustrate the machines under consideration, namely, machines for gear-tooth rolling, for lapping and for testing. The gears are tested for silent running after assembling on shafts, the test consisting in applying various loads at different speeds to detect noisy operation.

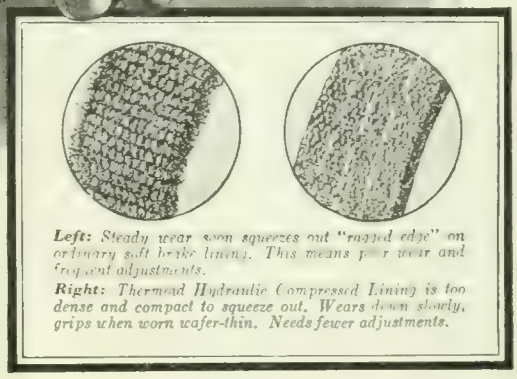
GEAR MAKERS SEEK TO EXPAND INDUSTRY BY FINDING NEW USES FOR PRODUCT. By P. M. Heldt. Published in *Automotive Industries*, Nov. 1, 1923, p. 903.

This article gives an account of a recent meeting of the American Gear Manufacturers' Association. An interesting feature of the meeting was a paper outlining methods for correcting errors in milled gears. In connection with the idea that in machining gear teeth by this process a cutter which is correct for producing gears with a given number of teeth is incorrect for any other number, it was pointed out that, in practice, errors of this kind are slight and that a cutter suitable for one series of numbers can, when necessary, be used to produce gears with a different number of teeth by slightly modifying the depth of the cut. When it is desirable to provide more backlash on the gears than is present when they are cut to the theoretical depth, this result, it is claimed, may be accomplished by sinking the cutters deeper into the blank.

The Committee on Composition Gearing reported work done in an endeavor to evolve a horsepower rating for gears made of phenol condensation products, six of which are on the market. Experiments testing the strength and endurance of these six products showed fairly consistent results for four of the materials, but two fell far below the others.

(*Continued on p.* 12)





Left: Steady wear soon squeezes out "ragged edge" on ordinary soft brake lining. This means poor wear and frequent adjustments.

Right: Thermoid Hydraulic Compressed Lining is too dense and compact to squeeze out. Wears down slowly, grips when worn wafer-thin. Needs fewer adjustments.

Here's why

it *wears* down

slowly instead of *mashing* down quickly

Take a short strip of Thermoid Compressed Brake Lining. See how compact it is, as compared to an ordinary lining. Feel its density, its weight. This solid compactness makes Thermoid grip evenly and wear longer.

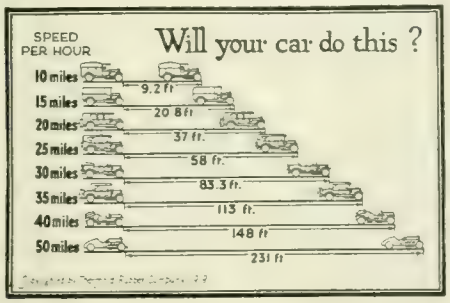
Tremendous hydraulic pressure — 2000 pounds of it — takes all further "give" out of Thermoid. In its place is compressed *40% more material* than is found in any other brake lining made.

This compression makes Thermoid *wear* down slowly instead of *mashing* down quickly.

Thermoid doesn't "squeeze out"

The tremendous hydraulic pressure on Thermoid takes out all excess "give." That is why Thermoid is the last to show the "ragged edge" between drum and brake band.

Send for our booklet, "The Dangers of Faulty Brakes." It contains valuable information and complete records of brake lining tests which every engineer will be glad to have on hand.



Famous Thermoid Standard Chart—shows distances in which car should stop if brakes are efficient. Brakes lined with Thermoid meet these standards.

THERMOID RUBBER COMPANY

Factory and Main Offices: Trenton, N. J.

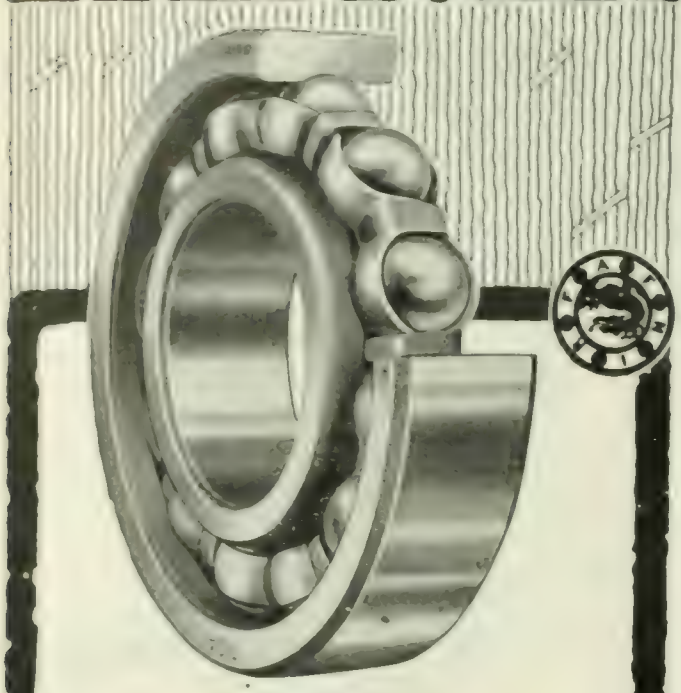
New York, Chicago, Los Angeles, Detroit, Atlanta, San Francisco, Boston, Cleveland, Kansas City, Seattle, London, Paris, Turin

Thermoid Brake Lining

Hydraulic Compressed

Makers of "Thermoid-Hardy Universal Joints" and "Thermoid Crolide Compound Tires"

FAFNIR



FAFNIR Ball Bearings possess many distinctive advantages among which are the following:—

1. **High carbon chrome alloy steel,** resulting in combined hardness and toughness.

2. **Thorough heat treatment,** and not case hardening which is only skin deep.

3. **Turned balls,** insuring absolute uniformity and resistance to wear.

4. **Deep race grooves,** affording greater load carrying capacity.

5. **Pressed steel ball retainer,** which is practically destructionless and frictionless.

Fafnir Ball Bearings are manufactured in ALL standard types and sizes. There's a Fafnir for every bearing purpose.

THE FAFNIR BEARING COMPANY

New Britain, Conn.

NEW YORK, N. Y.
3 Columbus Circle

NEWARK, N. J.
271 Central Ave

PHILADELPHIA, PA.
1427 Fairmont Ave

NOTES AND REVIEWS

Continued

In the discussion of the report of the Tooth Form Committee, it was brought out that flats on the tooth faces of hobbed gears could be considerably reduced by increasing the number of teeth in the hob.

In the report of the Differential Committee, drawings were presented of a four-pinion differential gear that is intended as recommended practice for future design.

The Metallurgical Committee stated that cast steel requirements can be grouped under three heads, namely, castings to be case-hardened, untreated castings and heat-treated castings.

Other topics discussed at the meeting included industrial relations, training shop executives, an intensive 2-year engineering course, keyway standards, the design of hobs for cutting worm gears and uses for gears other than in the transmission of power.

LAWS OF BEARING AND DRY FRICTION SIMILAR WHEN LOADS ARE HIGH. By P. M. Heldt. Published in *Automotive Industries*, Sept. 20, 1923, p. 573.

In this, the first in a series of four articles analyzing recent developments in lubrication theory and practice, the author begins by defining "boundary lubrication," tracing the history of this theory and calling attention to the diversity of opinion regarding this theory. An oil-testing machine is described, from the operation of which static friction coefficients were derived for 11 lubricants with two different combinations of metal, mild steel on cast iron and mild steel on gun metal. The conclusion is drawn from the results that static friction varies not only with oil but also with the metal of the bearing and that "oiliness" is rather an effect produced upon the metal surface than a property of the lubricant as a liquid.

RESEARCH REVEALS LAWS OF FRICTION IN LUBRICATED BEARINGS. By P. M. Heldt. Published in *Automotive Industries*, Oct. 11, 1923, p. 735.

The second article in the series describes experiments that have been made at various times to determine the effects of surface velocity, temperature, character of material and character of lubricant on frictional loss.

OPINIONS VARY REGARDING USEFULNESS OF OIL GROOVES. By P. M. Heldt. Published in *Automotive Industries*, Oct. 18, 1923, p. 800.

Hydrodynamic principles applied to lubrication would lead to the conclusion that the best results would be obtained from grooveless bearings; this theory, however, assumes a constant oil-temperature, although observation shows that the oil rises in temperature while passing through the bearing. The function of the grooves receives consideration, in this the third paper of the series, as well as the proper form of the grooves.

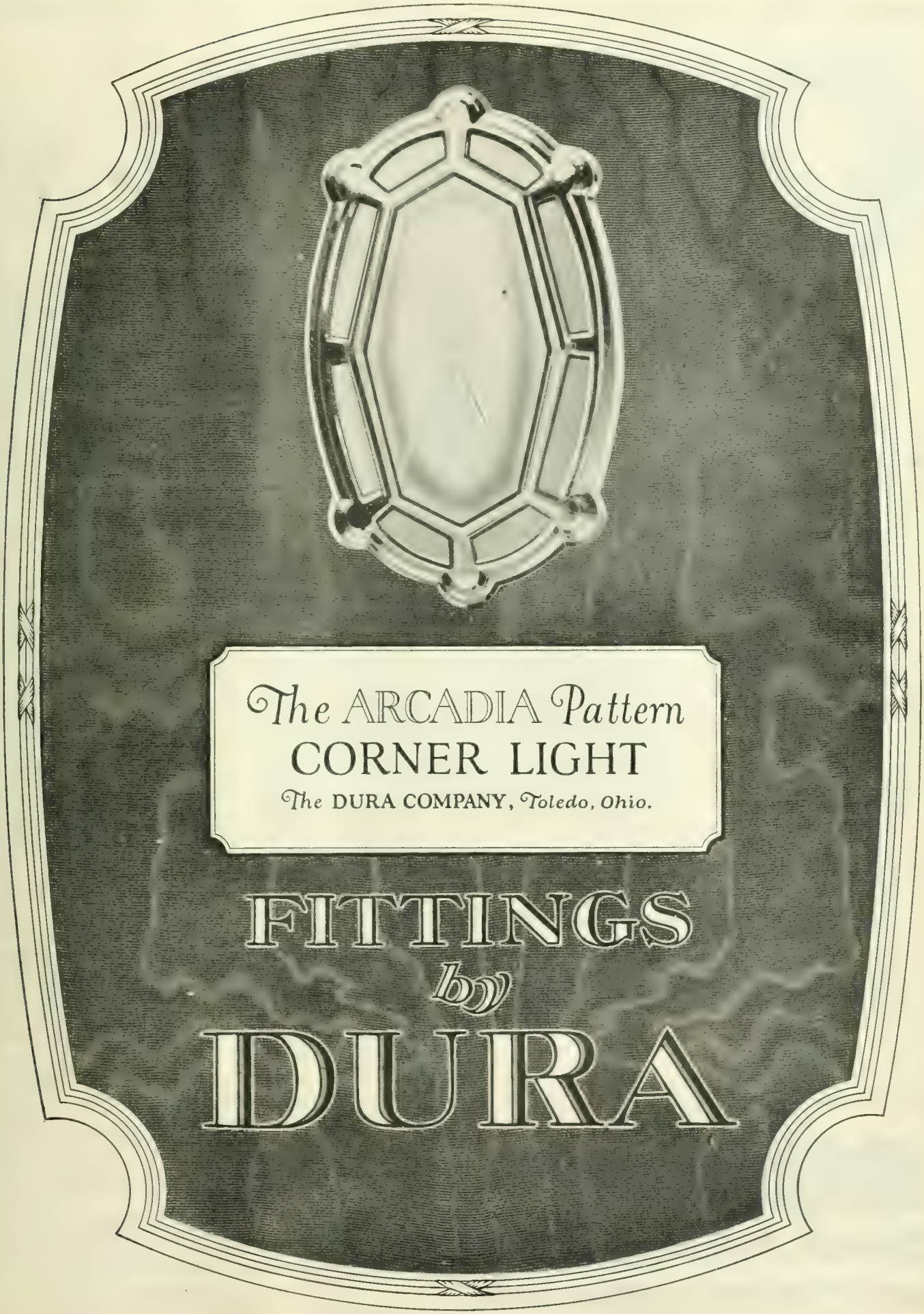
LUBRICATION VALUE OF OILS IS AFFECTED BY PROPERTIES OTHER THAN VISCOSITY. By P. M. Heldt. Published in *Automotive Industries*, Oct. 25, 1923, p. 842.

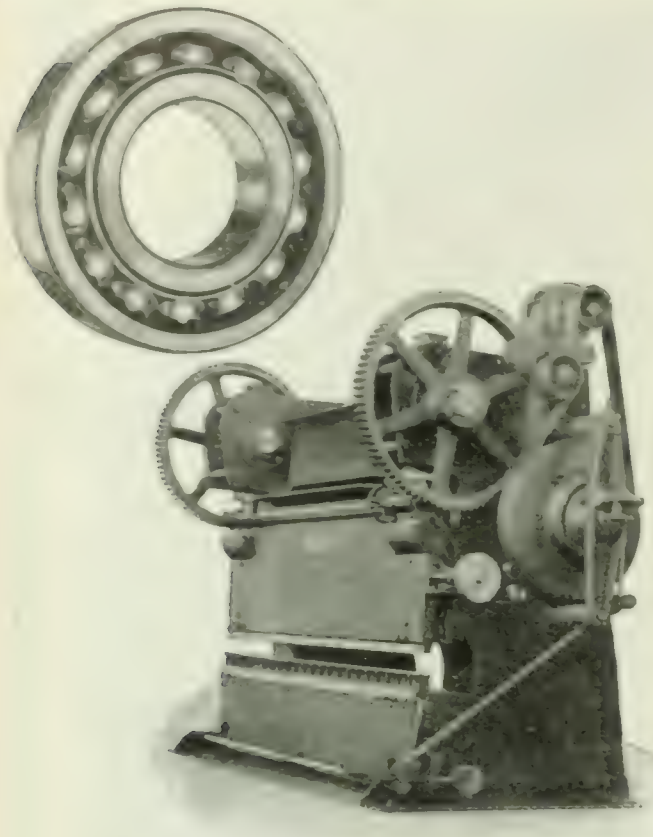
This, the final article in the series of four, shows that for the same general class of lubricants and within certain limits of loading, peripheral speed and fit, the friction of a bearing is directly proportional to the viscosity of the oil used, but when lubricants of different chemical characters are considered and the above limitations are removed, this relationship no longer holds, and other properties than viscosity have a part in determining the value of a lubricant. Oiliness is defined, capillarity as a factor in lubrication is discussed and the theory of colloids receives consideration.

THE STANDARDIZATION OF COMMERCIAL VISCOMETERS. By Madison L. Sheely. Published in *Industrial and Engineering Chemistry*, November, 1923, p. 1109.

After mentioning the need for the standardization of commercial viscometers and for the expression of results in terms that can be checked in other laboratories within a reasonable limit of accuracy, the methods of calibrating instruments of the capillary outflow type are considered, together

(*Continued on p.* 14)


The ARCADIA Pattern
CORNER LIGHT
The DURA COMPANY, Toledo, Ohio.
FITTINGS
by
DURA



Cincinnati Brake
or Plate Forming Machine

This interesting machine, in order to withstand the tremendous stresses without deflection or distress, is built up of steel throughout, instead of cast iron.

It is natural, in such a machine, that all important bearings, such as the bearings of the big clutch pulley, the idler on worm shaft—some eight bearings in all—are Gurneys.

Gurney Engineers are experienced in solving difficult bearing problems—let them help you with yours.

GURNEY BALL BEARING CO.
402 Chandler St., Jamestown, N. Y.

GURNEY
BALL BEARINGS

NOTES AND REVIEWS

Continued

with a typical calibration of the MacMichael torsional viscometer as it pertains to practical usage in the commercial laboratory. Liquids and solutions suitable for the standardization of commercial types of viscometers are briefly discussed, and non-volatile oils are in general recommended for calibrating purposes at comparatively high viscosities.

CONTROL OF AIRPLANES AT LOW SPEEDS. By Melvill Jones. Published in *The Journal of the Royal Aeronautical Society*, October, 1921, p. 473.

Calling attention to the number of accidents that have occurred because of pilot's losing control when approaching the landing ground at the minimum possible speed, the author discusses the desirability of developing some broad basis upon which airplanes, under design, can be examined for controllability, as for strength and performance. The tendencies of a stalled engine that if not checked produce the spin which often precedes a fatal accident are analyzed. The necessity is stressed for control over the orientation of the airplane during slow flying, and means of securing such control are discussed.

THE WREN LIGHT AIRPLANE. Published in *Engineering*, Oct. 26, 1923, p. 526.

A description of the Wren light airplane, accompanied by three diagrams and two photographs, includes the following statements:

> The performance figures, based on an engine output of 7 hp. which is obtained at 2600 r.p.m., are as follows:
>
> | | |
> |---|---|
> | Full Speed, m.p.h., | 50 |
> | Landing Speed, m.p.h., | 25 |
> | Climb, ft. per min., | 150 |
> | Ceiling, ft., | 7,000 |
> | Distance Required To Get Off, yd., | 50 to 70 |
> | Distance Required To Pull Up., yd., | 20 to 25 |
>
> Compared with the performance of a modern airplane of the usual design the figures given above are by no means striking at first sight, but when it is pointed out that they are obtained with a power loading of 54.3 lb. per hp., whereas the corresponding figures for commercial and service airplanes are about 15 and 12 lb. per hp. respectively, it will be seen that they are of a distinctly high order. The wings have a span of 37 ft. and a dihedral angle of 4 deg.

The English Electric Co., who constructed the Wren, is now designing, on similar lines, a light two-seated machine with dual control.

FABRIC STRESSES IN PNEUMATIC TIRES. By H. F. Schippel. Published in *Industrial and Engineering Chemistry*, November, 1923, p. 1121.

The definite commensurable stresses to which the fabric of a tire carcass is subjected are classified as follows: static, including stresses due to inflation-pressure and those due to deflection under load; dynamic, including traction and braking stresses and centrifugal stresses. A mathematical analysis is made of each type of stress with a view to expediting future work in tire design, and a brief consideration is given to indeterminate stresses due to road shocks.

THE ANALYSIS OF CHROME-VANADIUM STEEL. By G. E. F. Lundell, J. I. Hoffman, and H. A. Bright. Published in *Industrial and Engineering Chemistry*, October, 1923, p. 1061.

The methods and observations, recorded in this paper, deal chiefly with accurate volumetric procedures and are based for the most part on data obtained during the standardization of the Bureau of Standards standard samples of alloy-steels.

The determinations of carbon, sulphur and silicon in chrome-vanadium steel offer no serious difficulties and are dismissed with references to acceptable methods and some precautions that have been found desirable. After vanadium

(Concluded on p. 16)

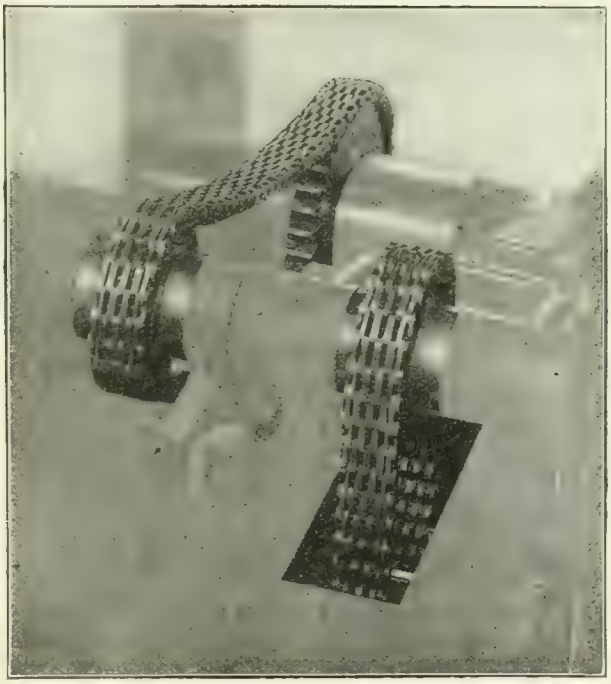
"WHITNEY"

LONG SERVICE CHAINS

SILENT TYPE

POSITIVE

FLEXIBLE



EFFICIENT

DURABLE

GREATER SERVICE

At Lower Cost

The Whitney Mfg. Co., Hartford, Conn.

CHAINS KEYS AND CUTTERS HAND MILLING MACHINES

NEW YORK
L. C. Biglow & Co., Inc.
243 W. 55th St.

BOSTON
George C. Steil
740 Commonwealth Ave.

PHILADELPHIA
R. J. Howison
624 Race St.

SAN FRANCISCO
A. H. Coates Co.
770 Mission St.

SEATTLE
A. H. Coates Co.
1115 East Union St.

MULTIPLE DISC CLUTCHES

"DETLAFF"

JUST as a chain is no stronger than it's weakest link—no engine is superior to the clutch. The clutch *must* transmit the engine power, without shock to the rear end. It must be powerful enough to pass on *all* of the power and yet take hold gently.

THERE *is* no argument as to the *efficiency* and *dependability* of the MULTIPLE DISC CLUTCH. It is one of those self-evident facts that we cannot get away from.

THE question is:—Why should *you* use the "VELVET CLUTCH WITH THE BULL-DOG GRIP?" Because in the long run, it is the least expensive type—it's softness of engagement lends an added charm to that engine of yours—and its action *under the foot of the driver*, creates favorable comment—the most effective form of advertising known.

THE designers of the world's most successful motor vehicles—with few exceptions, specified and *continue* to use, THE MULTIPLE DISC CLUTCH.

A sheet of facts for "the asking."

A. J. DETLAFF CO.

Detroit, Mich.

NOTES AND REVIEWS

Concluded

has been reduced to the quadrivalent state, the determination of phosphorus also offers no trouble and hence no detailed descriptions of the well-known methods for phosphorus are given. On the other hand, the determinations of manganese, chromium and vanadium offer some difficulties, and these are discussed at greater length and desirable methods that are not widely known are given.

MANUFACTURE OF RUBBER AND PYROXYLIN COATED FABRICS DIFFERS WIDELY. Published in *Automotive Industries*, Oct. 18, 1923, p. 794.

This paper, describing the manufacture of rubber-coated Fabrikoid, enumerates the important ingredients used, tells the method of preparing the coating and of regulating the thickness of the coating, discusses the serviceability of various colors and the three grades of lustre and concludes with three paragraphs of points that users should consider.

TEST SHOWS NO ABRASIVE IN BRONZE BUSHINGS. Published in *American Machinist*, Nov. 8, 1923, p. 689; reprinted from *Grits and Grinds*, September, 1923.

Describes an experiment, resulting in the conclusion that no abrasive is imbedded in the metallic surface as a result of the grinding operation.

GENERAL MOTORS DEVELOPS POROUS BEARING METAL. Published in *Automotive Industries*, Oct. 18, 1923, p. 793.

Gives a brief description of a new porous, oil-absorbing, copper-tin bearing bronze, called Durex, possessing a low coefficient of friction and an unusual ability to resist wear. The paper describes the method of installation of Durex bearings and gives directions for the best results from their use. The physical properties of the metal are listed as follows: Brinell hardness, 30-40; scleroscope hardness, 15-18; modulus of elasticity, 2,500,000; weight, 3.5 oz. per cu. in.; specific gravity, 5.40; oil absorption, 25 per cent by volume; compressive elastic-limit, 2000 to 10,000 lb. per sq. in., depending on composition.

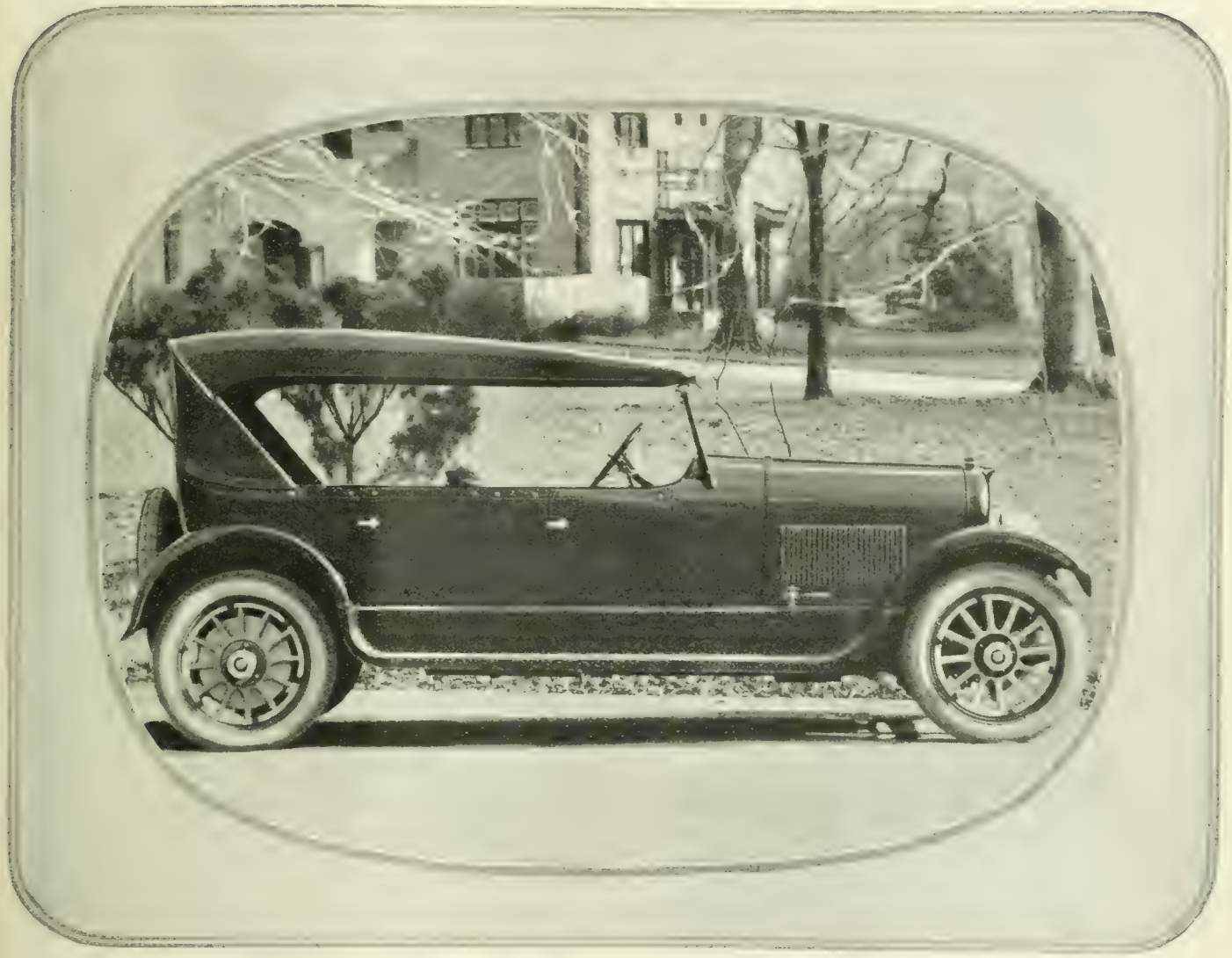
THE MOTORAILER WHEEL FOR MOTOR VEHICLES. Published in *Engineering*, Oct. 12, 1923, p. 472.

This short article, illustrated by seven diagrams and two photographs, is concerned with a wheel system that can be converted from the form required for railway or tramrail service to one suitable for the road and the reverse. It has been demonstrated that the conversion from road to rail service, including the removal of four tires and rims and the locking of the steering gear, can be effected by two mechanics in about 8½ min., while the reverse operation can be accomplished in 29 min.

The motor wheel is of the rail-track type, made of high-carbon steel. To convert this into the road form, a cast-steel rim, with a ¼-in. gap cut out of it in the way common with piston-rings, is placed around the wheel to provide the requisite horizontal face for the rubber tire. The rim is held in place by six bolts that pass through the holes at the thickened top ends of the spokes; these bolts have sector-shaped heads that engage in recesses cut into the underside of the rim and are fitted with screwed pins for use in liberating the rim once the nuts are removed. The shafts of the bolts pass through the rim of the wheel and the nuts bear against the inner face.

ELECTRIC RAILWAY AND TRUCK TRANSPORT COMBINED BY USE OF CONTAINER CARS. By D. M. McDonald. Published in *Automotive Industries*, Oct. 4, 1923, p. 678.

Gives an account of a plan to combine railway cars and motor trucks for the transportation of freight. Among the advantages mentioned are economy and the convenience of door-to-door service. Demountable containers, loaded by the shipper, will be transferred from the truck to the railway car, from the car to the truck again and then to their destination, thus necessitating the minimum of handling. The container is really a small-sized freight car, being used as a substitute for the large car on less-than-carload shipments; all containers are on ball-bearing wheels and the largest, fully loaded, can be moved by one man.



Distinctive

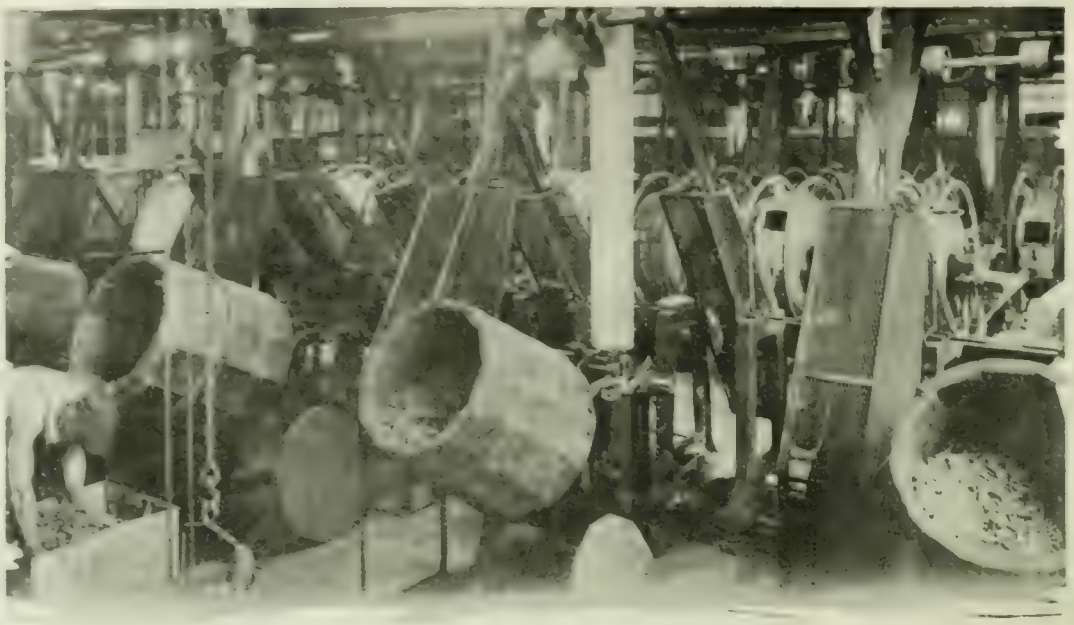
NEVERLEEK adds the touch of elegance that distinguishes fine cars. Distinctive in appearance, for years it has been the standard top material of the leading automobile manufacturers and custom-body builders. Each year brings increased recognition of its pre-eminence.

Its beautiful surface reveals style and smartness; rugged endurance is built into the texture. Neverleek holds its cut and fit throughout the life of the car, and maintains its original lustre and trimness under severest conditions. Blistering sun cannot fade it or crack it. Heavy windows cannot make it sag or stretch.

Neverleek samples in different grains and with many styles of linings, with prices, will be sent to automobile manufacturers and top and body makers upon request.

NEVERLEEK
TOP MATERIAL
Trade Mark Reg. U. S. Pat. Off.

F. S. CARR COMPANY, 31 Beach Street, Boston, Mass. ***Branch Offices,*** **Detroit, St. Louis, Atlanta**



Days are Consumed in Removing .0002 inch From Atlas Balls in Polishing and Burnishing

AS EACH batch of Atlas Balls go to the polishing department a few sample balls are measured on Minimeters to determine their exact size. In this way the amount of material — generally about .0002 inch — that should be removed in polishing is made known, permitting the length of the polishing operation to be set accordingly.

The polishing operation consists of tumbling the balls very slowly but continuously for from 20 to 40 hours in barrels containing Vienna lime and water. Upon being removed the balls are dried in saw dust and then rolled for several hours in wood tumbling barrels containing strips of soft kid leather which give to the balls their exceptionally brilliant finish.

The finished balls which are true in size and sphericity to within plus or minus of 1 2 of 1/10,000 inch, are then surface inspected and gauged. Nothing is taken for granted. That is one of the reasons why Atlas Balls are noted for being unsurpassed in accuracy, quality and endurance.

Hultgren BRINELL BALLS *Process*

The development of a new ball for Brinell Testing Machines—combining uniformity and greater hardness with extreme accuracy—has been completed. Balls made by this process are now available.

ATLAS BALL COMPANY

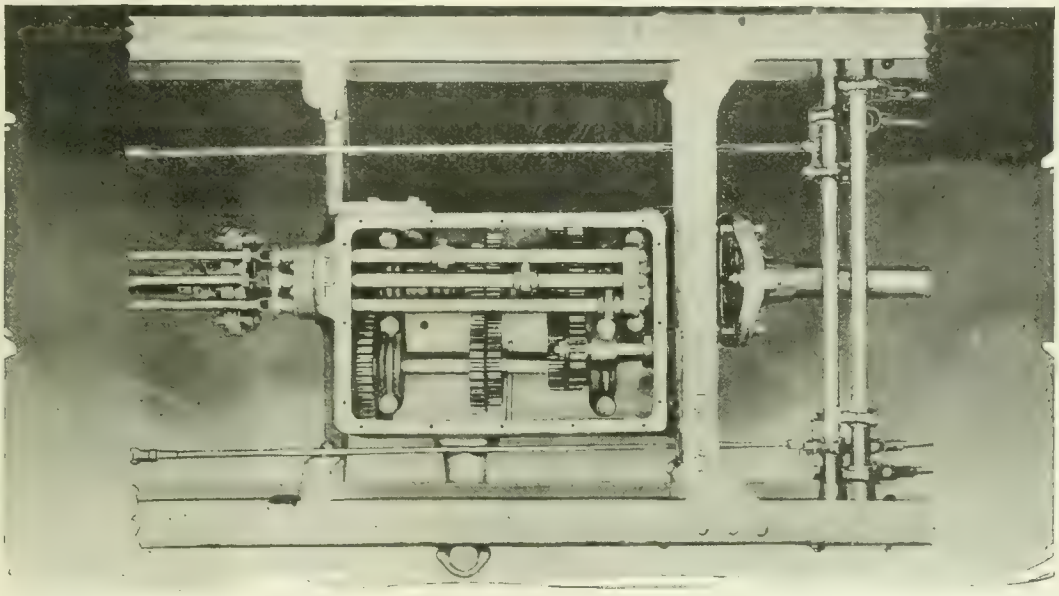
Glenwood Ave. at Fourth St. - - - Philadelphia

ATLAS STEEL BALLS

ALSO BRASS, BRONZE, MONEL AND SPECIAL METALS

Made Under SKF Specifications

SKF



Ball Bearings on Transmissions
Keep Gears in Proper Mesh for Life of Car

IF the bearings on the transmission wear, the gears no longer mesh properly and become noisy and inefficient. Furthermore the gear teeth rub and grind upon each other and soon loose their proper shape with the result that no amount of bearing adjustment can restore the worn gears to proper mesh.

On this motor-truck transmission Skayef self-aligning ball bearings used between the shifting clutch shaft and the main drive shaft as well as on the counter shaft insure the maintenance of the original accurate settings of these parts for the normal life of a truck.

Having an extremely small co-efficient of friction and being made of special alloy steel hardened uniformly throughout this type of bearing absorbs very little power and develops no discernible wear.

Because of their accuracy and great endurance SKF marked ball bearings are particularly well adapted to use on vital automotive parts. Proper bearing selection is insured through the close co-operation of our engineers.

THE SKAYEF BALL BEARING COMPANY

Supervised by SKF INDUSTRIES, INC., 165 Broadway, New York City

1074

Normal View *Deflected View*

BALL BEARINGS
The Highest Expression of the Bearing Principle

ATWATER KENT

SERVICE

COVERS THE CONTINENT

ATWATER KENT OFFICIAL REPAIR STATION IGNITION

The Sign of Efficient Service

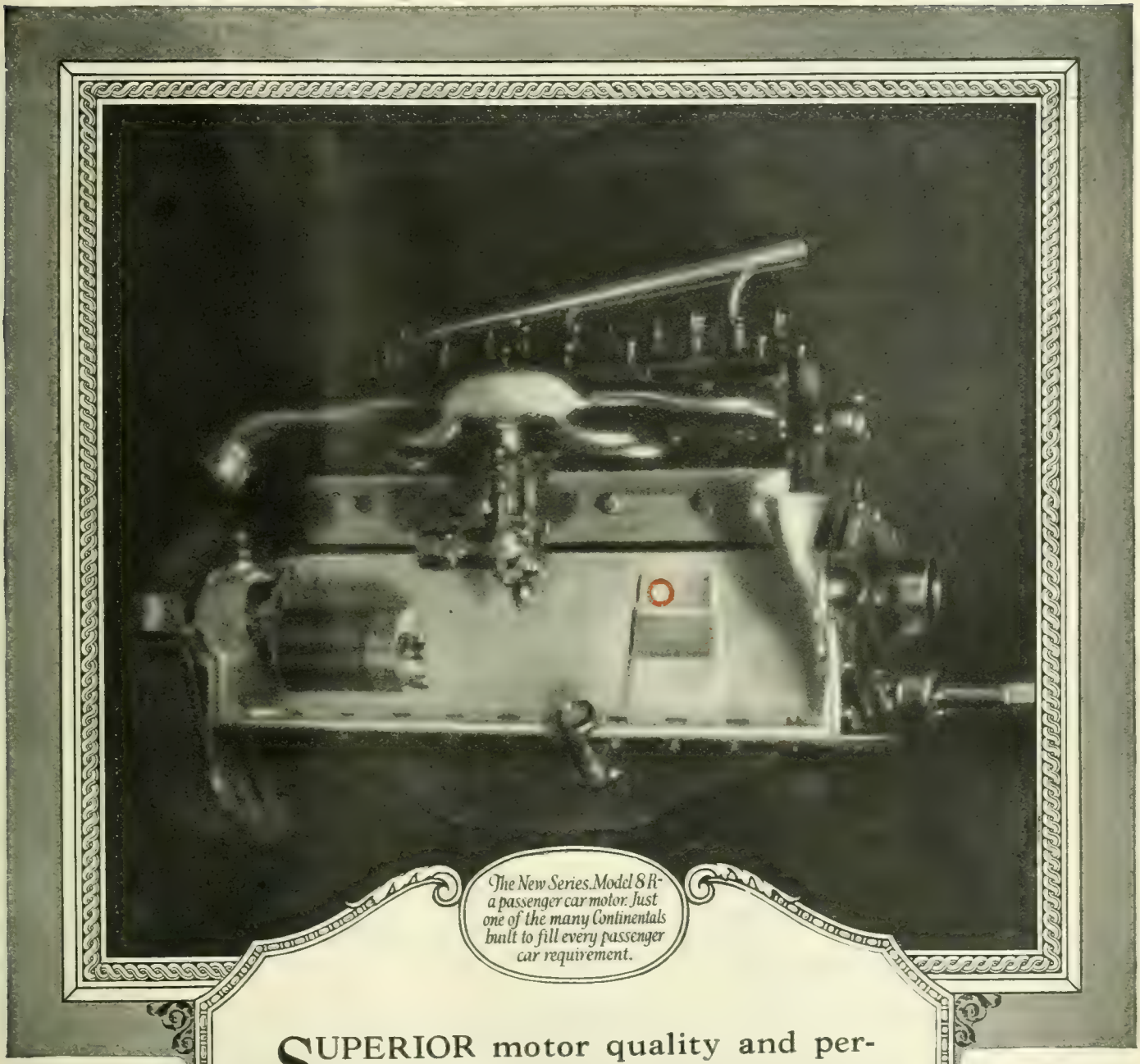
THERE are over 600 ATWATER KENT Official Repair Stations conveniently located throughout the United States and Canada—competent to render dependable efficient service on ATWATER KENT Starting, Lighting and Ignition Systems.

ATWATER KENT MANUFACTURING CO.

4961 STENTON AVENUE, PHILADELPHIA, PA.

Makers of

THE WORLD'S HIGHEST GRADE IGNITION
STARTING AND LIGHTING



The New Series Model 8 R- a passenger car motor. Just one of the many Continentals built to fill every passenger car requirement.

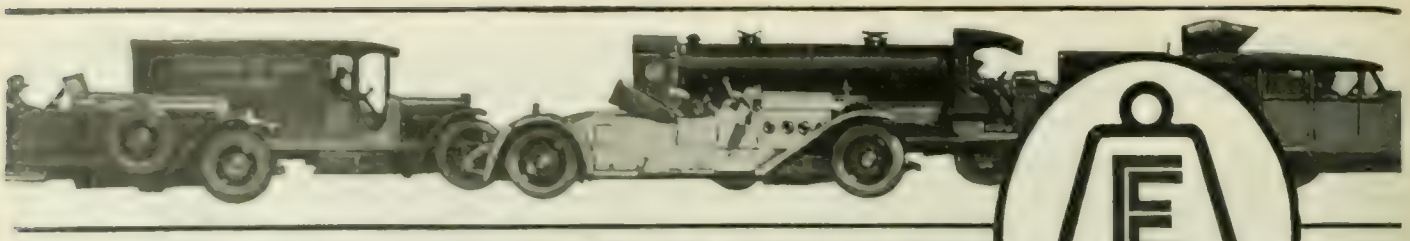
SUPERIOR motor quality and performance are reflected in the steadily increased production schedules of the car and truck builders who equip their product with the Continental Red Seal.

CONTINENTAL MOTORS CORPORATION

Detroit - Muskegon

The largest exclusive Motor Specialists in the world

CONTINENTAL MOTORS · Power that Serves the Nation · AMERICA'S STANDARD



Wherever the Eaton trade-mark is found the product which bears it is stamped as one of sterling quality. Eaton is a synonym for excellence in the automotive world.

"EATON MEANS EXCELLENCE"

EATON AXLES

It is a significant fact that the cars using Eaton Axles are among those generally accepted as leaders in quality.

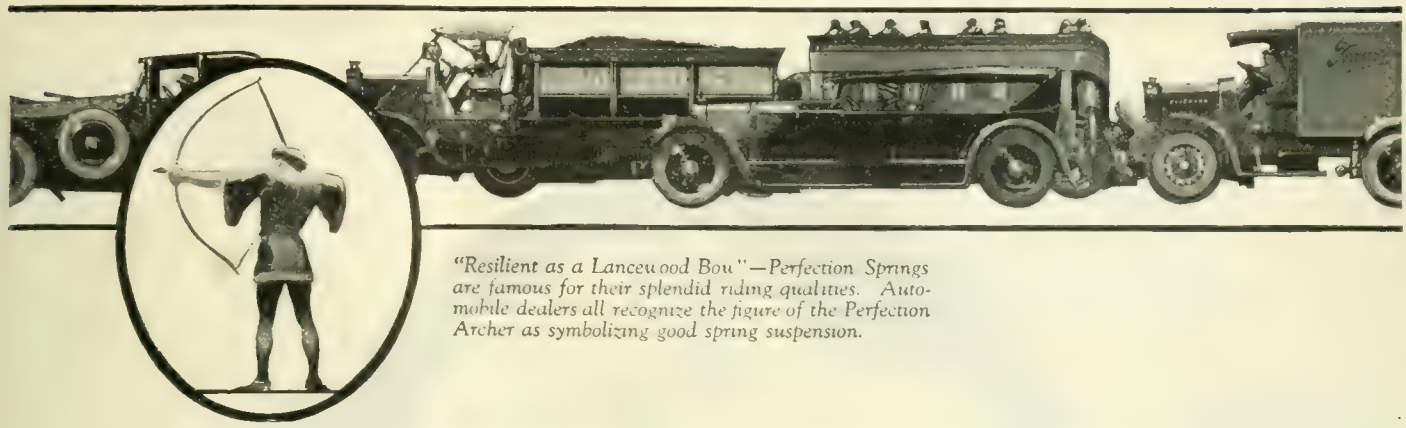
This simply means that Eaton standards are identical with those of the leading fine car manufacturers.

Correct design, careful selection of materials and extraordinary precision in manufacture, make certain that every Eaton Axle embodies the full efficiency of whatever type it represents —bevel gear, worm gear or double reduction.

Ask the builders of America's finest cars.

An EATON PRODUCT

The EATON AXLE & SPRING



"Resilient as a Lancewood Bow"—Perfection Springs are famous for their splendid riding qualities. Automobile dealers all recognize the figure of the Perfection Archer as symbolizing good spring suspension.

PERFECTION SPRINGS

Intelligent co-operation—both in engineering and production—with car and truck manufacturers, is one of the reasons for the "Perfection" reputation.

Our experience of seventeen years in working out the practical problems of spring suspension has been of untold value to our customers.

And in the actual making of the springs, our knowledge of steel and of heat treatment, our insistence on a uniformly good product, and our willingness to give extraordinary service when necessary, are mighty good reasons for car and truck builders preferring "Perfection."

An EATON PRODUCT

COMPANY ~ ~ ~ Cleveland

Your Triumph

The car specifications are the evidence of *your* triumph in engineering accomplishment.

Every part of that car is the result of thought and study on *your* part. More than anyone else in your company, *you* appreciate the full importance of every detail of its mechanical construction and the advisability of listing all vital parts in the printed specifications.

Automotive engineers readily admit that the ignition, starting and lighting cables comprise a vital unit.

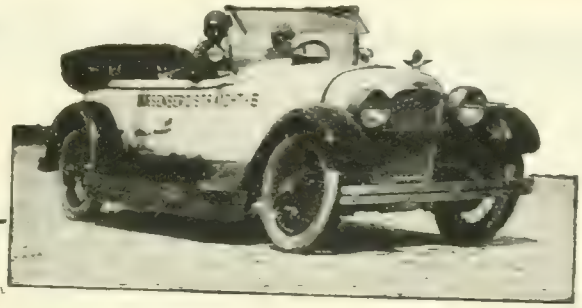
Many are recommending that Packard Cable be a part of the printed specifications.

The Packard Electric Company

WARREN, OHIO

MANUFACTURERS OF PACKARD AUTOMOTIVE CABLES

Send Us Your Blueprints and Specifications



BUILT TO OUTCLASS OUTRUN AND OUTLI

DUESENBERG STRAIGHT 8

THE GRAND PRIX CAR

DUESENBERG AUTOMOBILE & MOTORS CO. INC.
INDIANAPOLIS, INDIANA

May 8, 1923.

Johnson Bronze Corporation,
2 Mechanic Street,
Newcastle, Pa.

Gentlemen:-

It may be of interest to have photographs of the standard completely equipped stock Duesenberg Straight-Eight car which ran 3,155 miles, or a distance equivalent to that from New York to Los Angeles, upon the Indianapolis Motor Speedway without a stop. This test was under the sanction of the American Automobile Association and the direction of their official observers throughout the test and during the tear down following the test to check up the car.

Since you are furnishing us with material I know you will be particularly interested in knowing that your parts performed absolutely 100% during this test, and I am enclosing photographs showing the car in action, also photographs showing the supply car which made it possible for us to make this a continuous test, stopping neither for oil, gasoline, water or change of drivers.

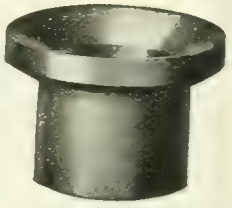
This made it possible for us to cover the distance in 50 hours 21 minutes at an average speed of 62.63 miles per hour. The test was a great deal more gruelling than these figures indicate because the first night we encountered six hours of rain which slowed the car down to such an extent that the succeeding two days had to be driven at speeds from 70 to 75 miles per hour in order to maintain the average and make up for the lost time.

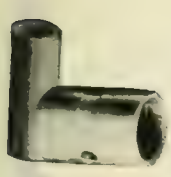
Yours very truly,

DUESENBERG AUTOMOBILE & MOTORS CO., INC.

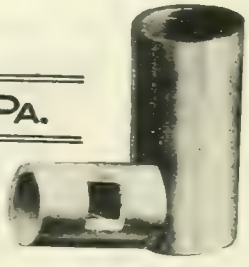
Chester S. Ricker,
General Manager.

CSR:SN
Encl.

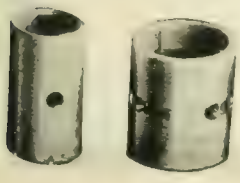




JOHNSON BRONZE CO. NEW CASTLE, PA.



BUSHINGS JOHNSON BEARINGS



Four-Wheel or Two-Wheel

Whichever way your brake decision may go, there's a selling job to be done on car-owners and car-dealers. They'll want to know *why*.

We believe it will be helpful to have the name and reputation of Timken as well as your own good name back of that next set of axles.

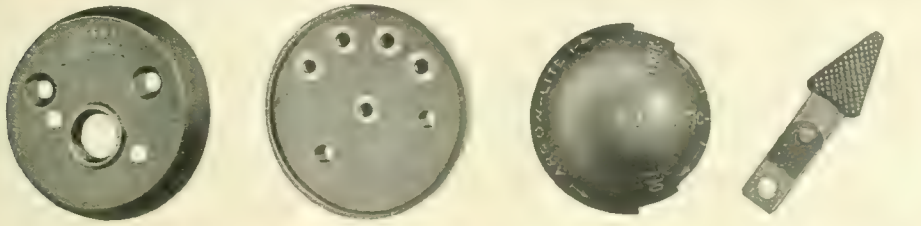
For "Timken" has always stood for safe and reliable brake action with the car owners of America.

THE TIMKEN-DETROIT AXLE COMPANY, DETROIT, MICH.
Sole Representatives in the British Isles:
AUTOMOTIVE PRODUCTS COMPANY, 3, Berners Street, London, W. 1.

No new chassis feature ever demanded more intelligent designing, construction and installation than do four wheel brakes—to assure safe operation.

BAKELITE

REG. U. S. PAT. OFF.



1 2 3 4 5

BAKELITE solves a precision assembly problem for ARROW-LITE

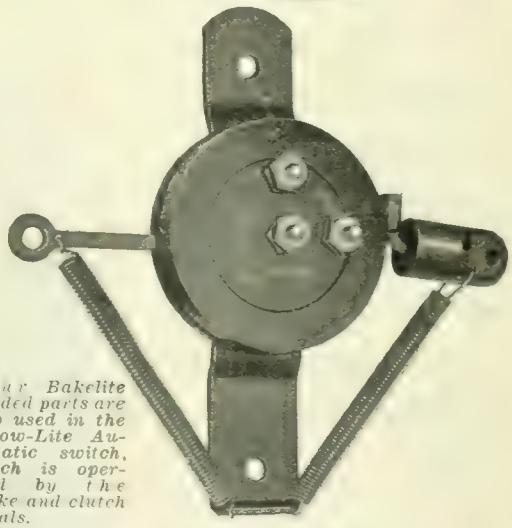
Only 1 5/8 inches in diameter, and with four separate electrical contacts to be provided for, this Arrow-Lite Signal Switch presented a difficult manufacturing and assembly problem.

How completely Bakelite molded parts met the requirements is clearly shown in the photographs above.

1. Base, molded with finished flanged hole for electrical conductors, and with sharp, clean-cut lettering.
2. Contact Block, molded with five metal contacts permanently embedded.
3. Cap, molded with lettering in sharp relief and with metal inserts for assembly screws.
4. Thumb Switch, with molded tip.
5. Complete Arrow-Lite Switch, an assembly of four Bakelite molded parts that snap together with "Watchcase" precision.

The adoption of Bakelite molded parts is simplifying design, reducing assembly costs, and improving quality, for many manufacturers.

Engineers, designers and production managers are cordially invited to enlist the cooperation of our research departments.



Four Bakelite molded parts are also used in the Arrow-Lite Automatic switch, which is operated by the brake and clutch pedals.

BAKELITE CORPORATION
247 Park Avenue, New York, N. Y.

Plants

Perth Amboy, N. J. — 636 W. 22d St., Chicago, Ill.
Bloomfield, New Jersey — Painesville, Ohio

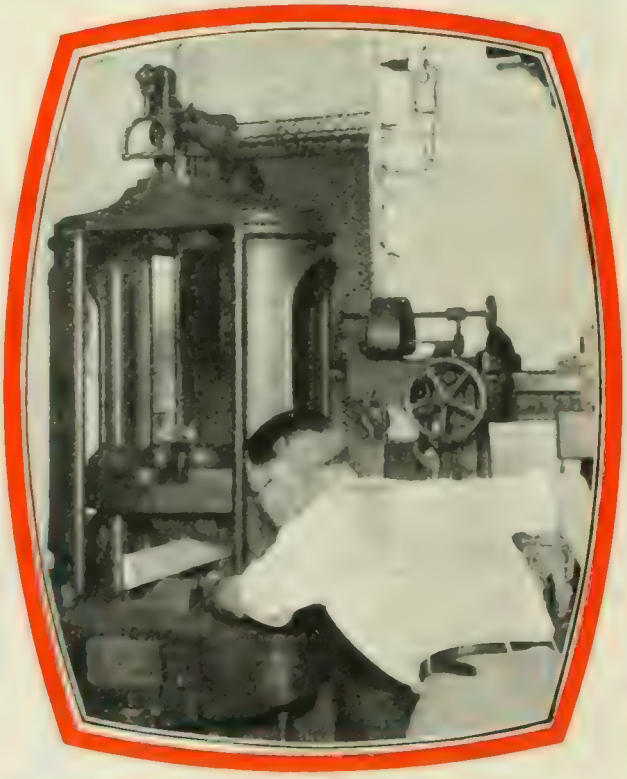
BAKELITE
Condensite
REDMANOL

are the registered Trade Marks for the Phenol Resin Products manufactured under patents owned by
BAKELITE CORPORATION

THE MATERIAL OF A THOUSAND USES

Remarkable Effect Of 400° Oxvar Body Enamelling Shown By Wood Test

OLD IDEAS of body finishing have been thoroughly upset by the Oxvar Method. By it, a wood-frame body is given 3 to 5 coats of enamel at 400° in 4½ to 7½ hours at less than ½ former finishing costs.



Perhaps the most vital and discussed feature of this surprising method is our unique way of protecting the wood frame from such high heat.

The success of tens of thousands of Oxvar finish bodies produced in the past 3½ years indicates, at least, that Oxvar Wood Cement protects the frame from harm. The several large manufacturers who have adopted Oxvar even count upon positive improvement—greater frame strength—and the permanent sealing of the pores so that absorption or loss of moisture is prevented.

As additional proof of these remarkable benefits we submit herewith the report of the Detroit Testing Laboratory.

OXVAR

OXFORD VARNISH CORPORATION

Main Office: EMPIRE BUILDING, DETROIT

Plant: TOLEDO, OHIO

ESTABLISHED 1903

THE DETROIT TESTING LABORATORY

3726 WOODWARD AVENUE

DETROIT, MICH.

November 17, 1923.

Oxford Varnish Corporation,
Detroit, Michigan.

Gentlemen:-

We have conducted an investigation of your "Oxvar" method of wood treatment and submit our report as follows:

Test pieces, each finished to about 1" x 1-3/4" x 14", were prepared from kiln dried Birch, Maple, and White Ash. All tests were made in triplicate so that averages could be obtained. Static bending tests were made on samples as received and after the "Oxvar" treatment, readings being taken of maximum load, and deflection at first failure in each case.

The "Oxvar" treatment was carried out in your laboratory, under our supervision, to simulate in every respect your standard procedure for treatment of automobile frames and subsequent enamelling of bodies, heating the pieces to a maximum temperature of 400 degrees Fahrenheit.

Results of Bending Tests.

	Maximum Load		Deflection	
	No Treatment	Treated	No Treatment	Treated
Birch	3,198 lbs.	3,442 lbs.	0.300 inch	0.225 inch
Maple	3,306 "	3,655 "	0.260 "	0.240 "
Ash	2,333 "	2,530 "	0.280 "	0.245 "

Samples placed on edge, 12 inches between supports, load applied in center.

In our opinion, the particular advantage of your treatment is that the pores of the wood are so sealed that absorption of moisture, with consequent swelling or warpage, is practically impossible.

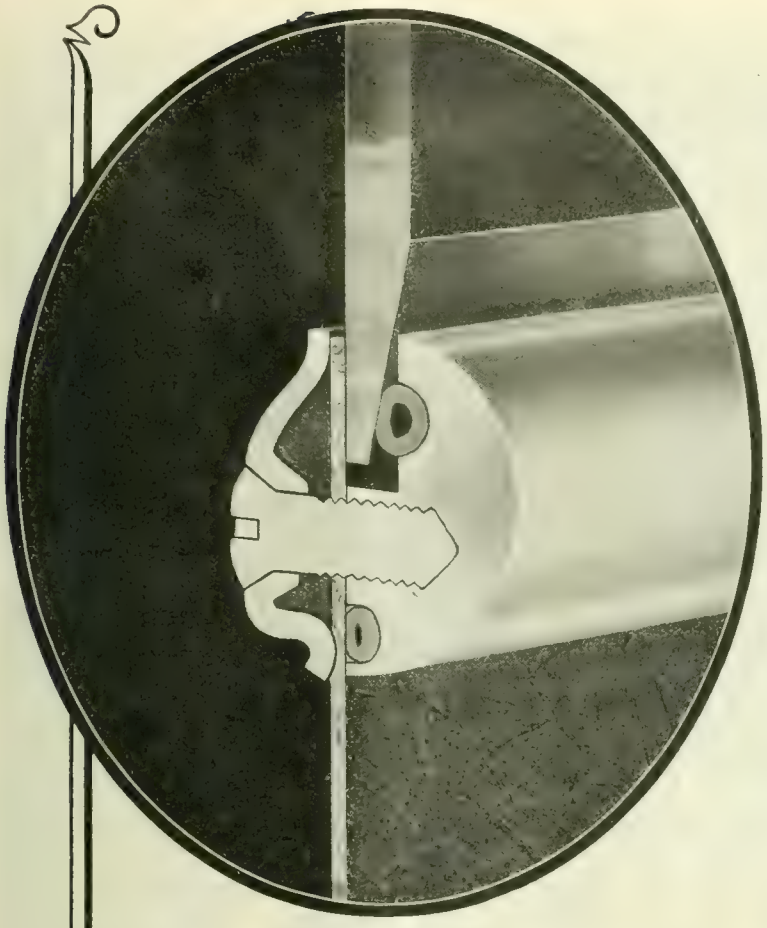
Yours very truly,

THE DETROIT TESTING LABORATORY.

Per C. L. Snyder
Registered Chemical Engineer

CLS/MB

Economy
Accuracy
Service
ALUMINUM
One part of a
motor car for
which there is
no substitute



Features of New Stewart Curtain Light

The inside frame is black enamel steel stamping designed to obtain the greatest possible strength, yet with sufficient flexibility to permit the insertion of glass of varying thickness.

The outside frame is an aluminum die casting, highly polished.

Live rubber tubing is cemented in the groove around the *outside edge* of the frame. The curtain fabric is pressed tightly against this live rubber, insuring a firm and permanent grip which prevents leakage.

Live rubber tubing is cemented in the groove around the *inside edge* of the frame, providing a cushion for the glass to prevent breakage and leakage. The glass cannot touch the metal frame.

The curtain fabric is trimmed inside of the frame, making the assembly very easy.

The nickel-plated steel screw is pointed to pierce the fabric where the frame is assembled.

Either beveled edge or plain crystal glass can be used.

Announcing to Automobile Manufacturers

A New Stewart Curtain Light

at competitive prices

This new Stewart Curtain Light is made to order for manufacturers who know that the good will of the purchaser depends upon entire satisfaction with every detail and appointment of the motor car.

The Rain-proof, Rattle-proof, Rust-proof features, which last longer than the car itself, are now available at the same price you pay for ordinary curtain lights.

There is no secret about the manufacturing process that accomplishes this economy. The inside frame is an enameled steel stamping. The outside our usual die cast aluminum frame. Its design combines great strength with sufficient flexibility to permit the use of either bevel or plain glass of varying thickness.

We experience great satisfaction in uncovering this source of economy and providing Stewart Curtain Light advantages for manufacturers at such remarkably low prices. We are prepared to design and produce this new curtain light in accordance with your specifications and requirements.

Stewart

STEWART MANUFACTURING CORPORATION
4535 Fullerton Avenue Chicago, Illinois

Stewart Curtain Lights

DU

WINDOW

Contributes a plan for lower-production

RA

REGULATORS

revolutionary

ing closed car

costs

THE DURA COMPANY

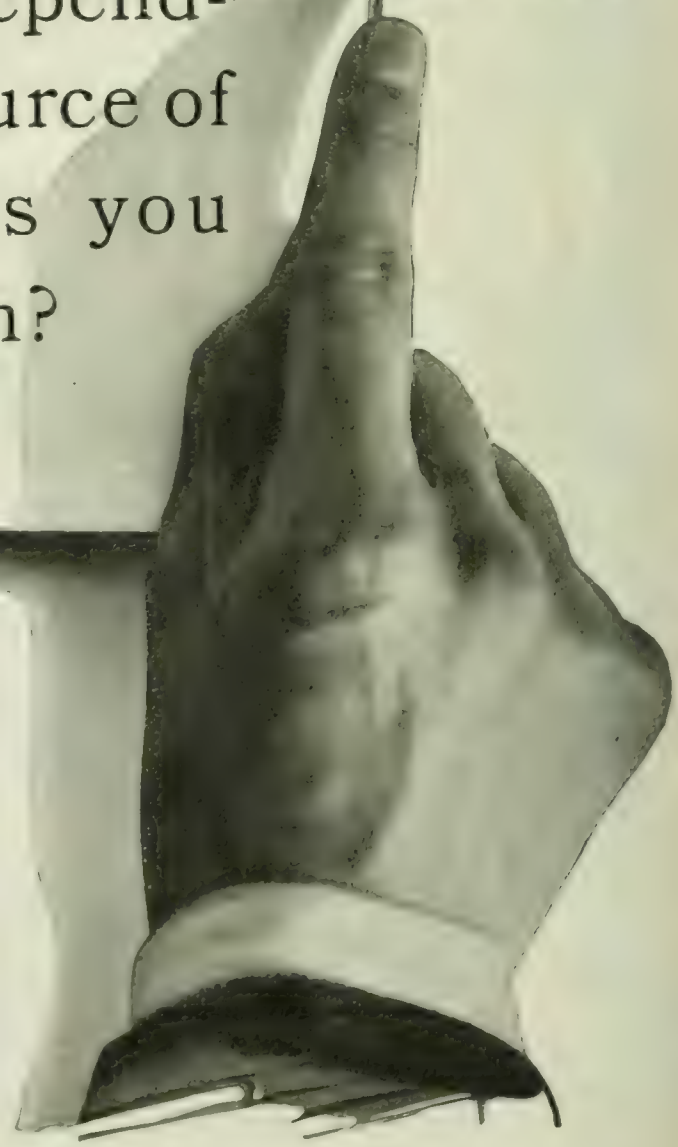
Toledo, Ohio

Raulang
AUTOMOBILE
BODIES

TO CAR MANUFACTURERS:

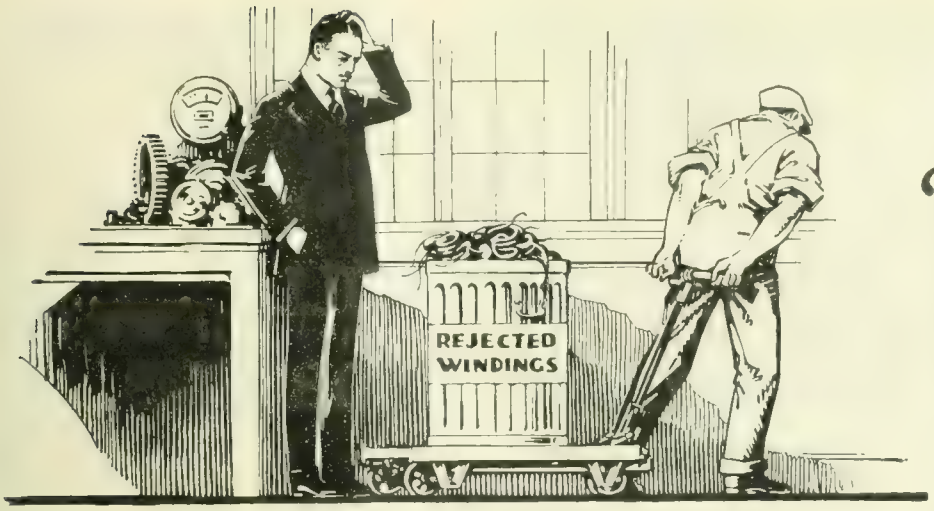
Was your closed-body builder this year as dependable a source of supply as you could wish?

Clip out this question and post it up where it will do the most good.



PERHAPS the most difficult way to make money in the automotive industry is in the building of closed bodies—and many have come to grief trying it! The fact that Raulang has made money and does make money is, in itself, evidence of Raulang ability to produce good bodies at satisfactory prices and in sufficient quantities. Every Raulang contract is backed by $4,000,000 capital and surplus. Also by a successful service to the industry that dates from the earliest days, and consists of notable body designing as well as efficient body manufacturing. Present expansion plans will make room for a limited amount of additional business. Why not avoid grief in 1924 by making certain—in advance—of the stability and permanence of your body builder?

RAULANG BODY DIVISION
The Baker R & L Co.
CLEVELAND, OHIO. U.S.A.



Don't blame the winder

THE coil winder often has to force the last turn of magnet wire into place and hammer down the bulges. He takes extra time for this—time that you are paying for. He sends up the cost of the winding. He also swells your volume of rejected windings.

But it isn't the winder's fault. If the wire is uneven and lumpy, the specified number of turns won't always go in the space. He must do the best he can, even though he does risk spoiling the job.

There *is* a way to cut down this waste. You *can* get a magnet wire that lines up, foot after foot, mile after mile, uniform in diameter—a wire that "*goes in the space.*"

Acme Wire "*goes in the space*" because it is uniform, free from lumps, bare spots, and imperfections of all kinds. The last turn always falls snugly into place. Its smooth, unvarying coat of insulation is of high dielectric strength.

Acme Wire has cut winding costs in many cases. With it the operator turns out not only more coils, but more that pass inspection. He winds coils that stay on the job for years.

Find out for yourself how and why Acme Wire can trim down your winding costs and boost your percentage of perfect windings. A postcard will bring our descriptive literature to your desk without obligation.

THE ACME WIRE CO., New Haven, Conn.

NEW YORK CLEVELAND CHICAGO

Some Users of Acme Magnet Wire

Atwater Kent Mfg. Co.
Azor Motor Mfg. Co.
Century Electric Co.
Dayton Engineering Laboratories Co.
Delco-Light Co.
Diehl Mfg. Co.
Domestic Electric Co.
Eisemann Magneto Corporation
Electric Auto-Lite Corp.
Electric Specialty Co.
Electrical Products Mfg. Co.
Eureka Vacuum Cleaner Co.
Ford Motor Co.
Gray & Davis, Inc.
Hamilton Beach Mfg. Co.
Holtzer-Cabot Electric Co.
Hoover Suction Sweeper Co.
Klaxon Co.
Robbins & Myers Co.
Sangamo Electric Co.
Sunlight Elec. Mfg. Co.
U. S. Auto Supply Co.
Wagner Electric Corporation
Western Cartridge Co.
Westinghouse Elec. & Mfg. Co.

Acme Wire Products

"Enamelite," plain enameled Magnet Wire; "Cottonite," Cotton-covered Enamelite; "Silkenite," Silk-covered Enamelite; Single and Double Cotton Magnet Wire; Single and Double Silk Magnet Wire. We also have a complete organization for the winding of coils in large production quantities.

Acme Varnished Insulations

Varnished Cambrics, Silks and Papers. Varnished Tapes in rolls; straight or bias. Varnished Tubing (Spaghetti).

Acme Radio Specialties

Audio Transformer windings.
Radio Frequency windings.
Magnet windings for Head Sets.
Enameled wire—especially the finest sizes, 40-44 B & S gauge.
Silk and cotton-covered magnet wire.
Enameled Aerial wire—single wire and stranded.

Illustrated Catalog on request to Engineers, Purchasing Agents, Executives and Operators.

AcmeWire

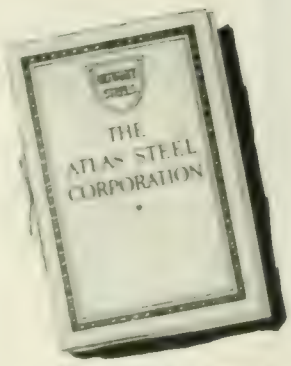
"It goes in the space"

TWO STEELS THAT WILL SOLVE YOUR HOT DIE PROBLEMS

Atlas Hot Die is offered for your severest conditions of hot die service. You require in such cases a red-hardness practically equal to that of high speed steel, yet the steel must be tougher than high speed and must not show checks when heated and cooled repeatedly. Atlas Hot Die is designed for such service.

For less severe conditions, economy may sometimes be effected by the use of Chrome Die. This steel has a degree of red-hardness adequate for milder service, and sometimes offers greater initial hardness where that is desirable.

We are anxious to confer with you on your hot-die problems.



steel problems.

High Speed Steels *Carbon Tool Steels* *Alloy Tool Steels*
Automotive Steels *Die Steels* *Special Analysis Steels*
Cold Drawn Products *Carbon and High Speed Drill Rod*

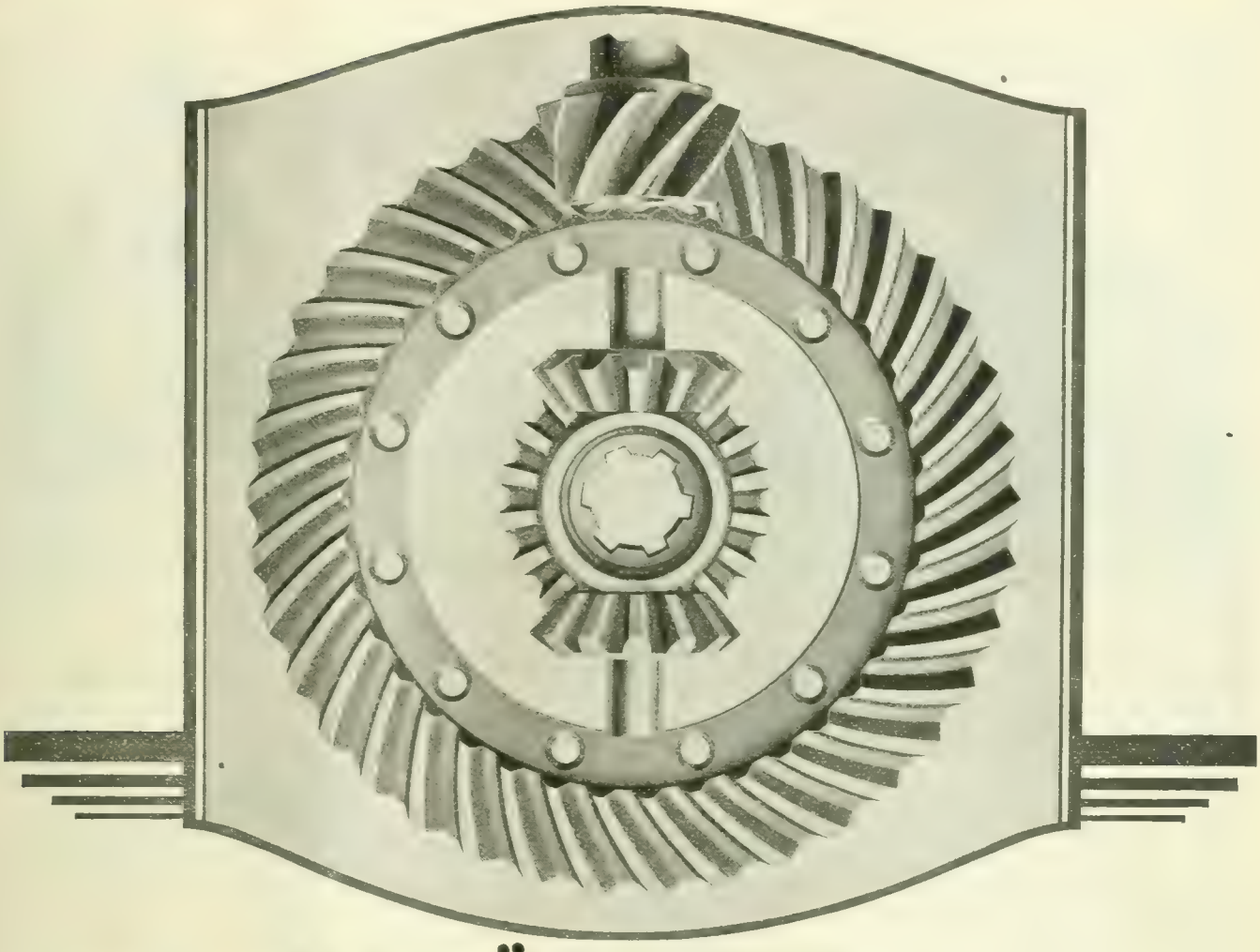
THE ATLAS STEEL CORPORATION

GENERAL OFFICES: DUNKIRK, N. Y.
Plants: DUNKIRK, N. Y. CHARLEROI, PA. WELLAND, ONT.

District Sales Offices: New York Boston Philadelphia Buffalo Pittsburgh Atlanta Indianapolis Cleveland Detroit Chicago St. Louis Syracuse

Warehouses: Dunkirk, N. Y. Charleroi, Pa. Boston Detroit Chicago Welland, Ont.

ATLAS FINE STEELS



"Van Dorn" Complete Differential Units

Excess capacity will permit us to take care of one or two more customers for "Van Dorn" Complete Differential Units. Let us check with you on your requirements.

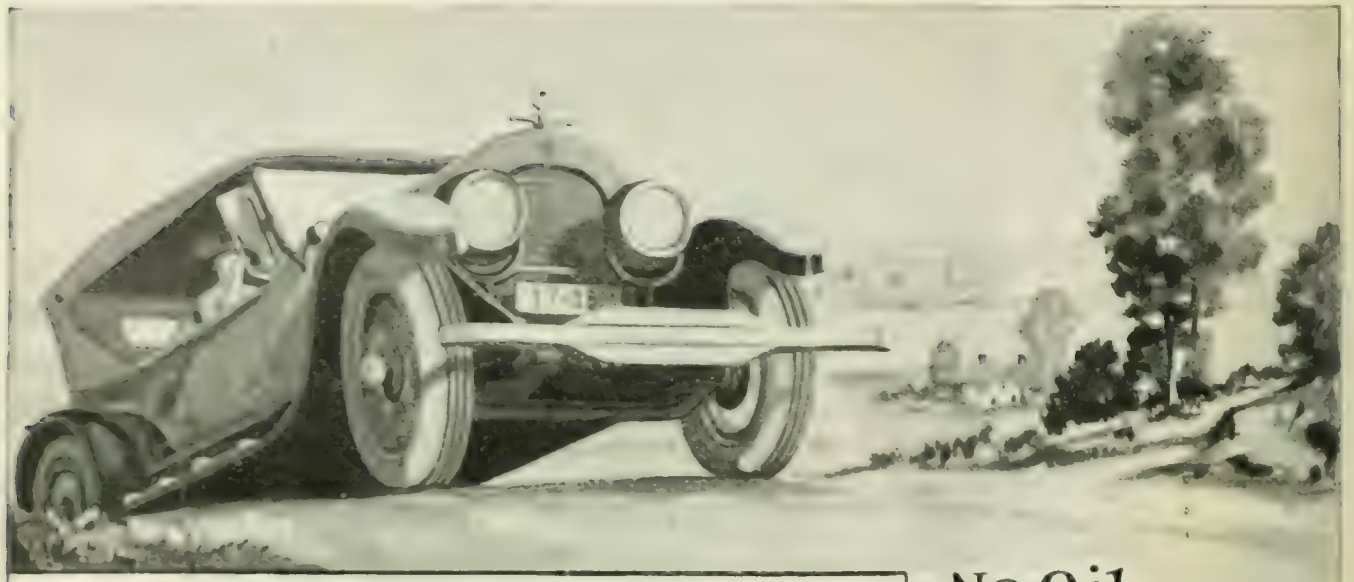
The Van Dorn & Dutton Company

Gear Craftsmen for over a Quarter Century

Cleveland, Ohio

"Van Dorn" GEARS

MEMBER OF AGMA



A new and better principle in Vacuum Fuel Feed-

Oil-Vac, the Kingston Vacuum Fuel Feeding System, does away entirely with the intake manifold as a suction source, utilizing instead the suction produced by the proper proportioning of the oil circulating pump.

With *Oil-Vac* there is certainty of increased suction with increased engine speed. When the greatest amount of fuel is needed, as in the case of long grades or at high speeds, the greatest amount is actually being delivered to the motor.

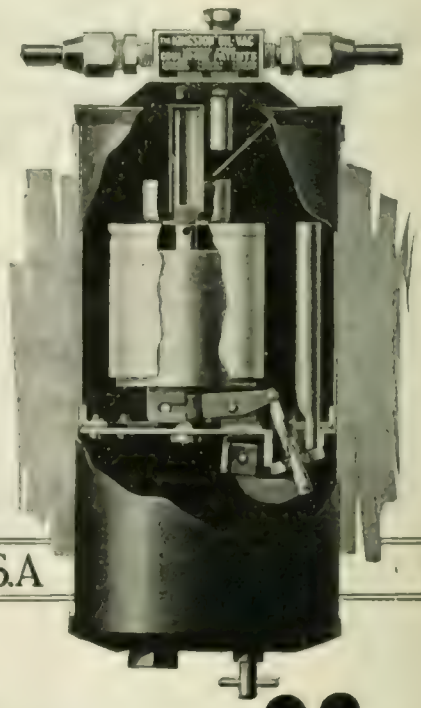
With *Oil-Vac* disturbance of carburetion is at a minimum, and crank case dilution is lessened to a marked degree. Oil runs cooler and lubrication is more efficient.

Automotive engineers generally are taking a deep interest in this *new* principle in vacuum fuel feed. A number of leading manufacturers have already adopted *Oil-Vac* as standard equipment, and many others are investigating its merits. A line to the manufacturers will bring complete information.

No Oil No Vac No Gas

With *Oil-Vac* the vacuum ceases when the oil supply becomes exhausted. No motor should run without oil, and no motor can run without oil for long without serious damage. This is one added feature of importance with *Oil-Vac*, a factor of safety that is worthy of consideration.

Send for the *Oil-Vac* Booklet



BYRNE, KINGSTON & CO. KOKOMO, INDIANA, U.S.A

Branches

"Oil-Vac"

Needs No Adjustment

The design of the Long Clutch is such that its silent, smooth and easy operation will continue indefinitely without need of attention or adjustment.

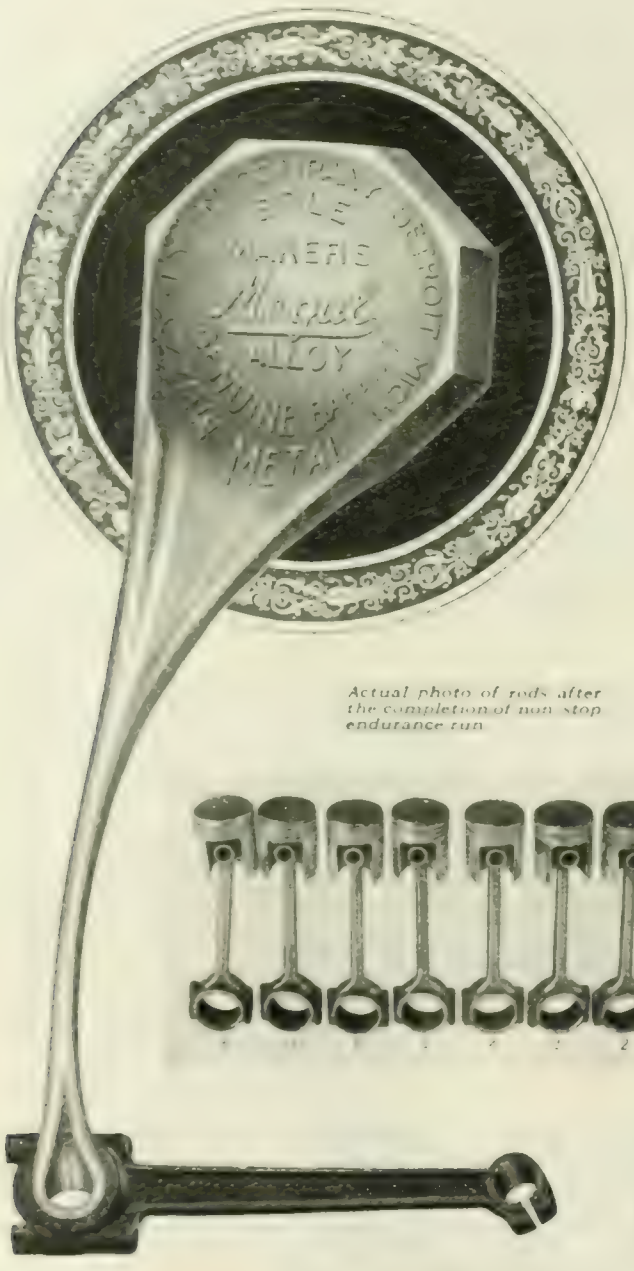
Moreover, gears synchronize so quickly that you can shift from high to second at *any* speed.

LONG MANUFACTURING COMPANY
DETROIT, - - - - - MICHIGAN

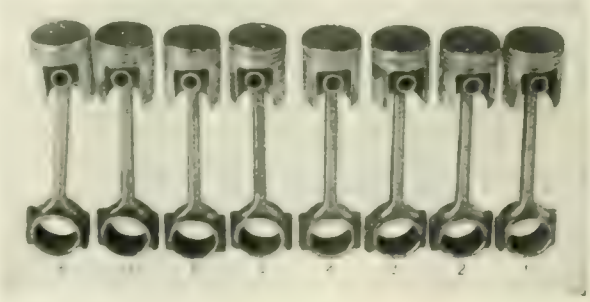
LONG CLUTCH

LONG PRODUCTS — RADIATORS AND CLUTCHES

Performed 100% In Severe Test



Actual photo of rods after the completion of non-stop endurance run



Rushing through space at an average speed of 62.63 miles, and at times exceeding 75 miles, per hour over a 3,155 mile course without stop subjects bearings to a strain that would never be demanded under ordinary conditions of driving.

Mogul Alloy Genuine bearing metal was used in the stock Duesenberg straight eight five-passenger touring car non-stop run on the Indianapolis Speedway, April 27, under the direction of the A. A. A., a distance equal to that between New York and Los Angeles being covered in 50 hrs., 21 min., 1 sec.

After this test run the engine was torn down under the supervision of the official observers of the A. A. A., with the result shown in the following letter to this company:

"I know you will be particularly interested in knowing that your parts performed 100% during this test."

Signed
DUESENBERG AUTOMOBILE & MOTORS CO., INC.
Chester S. Ricker, General Manager

MUZZY-LYON COMPANY
Detroit, Michigan

Mogul

Engine Bearings *and* Bearing Alloys

GEARS

THERE is more to forging a gear blank than simply making a forging.

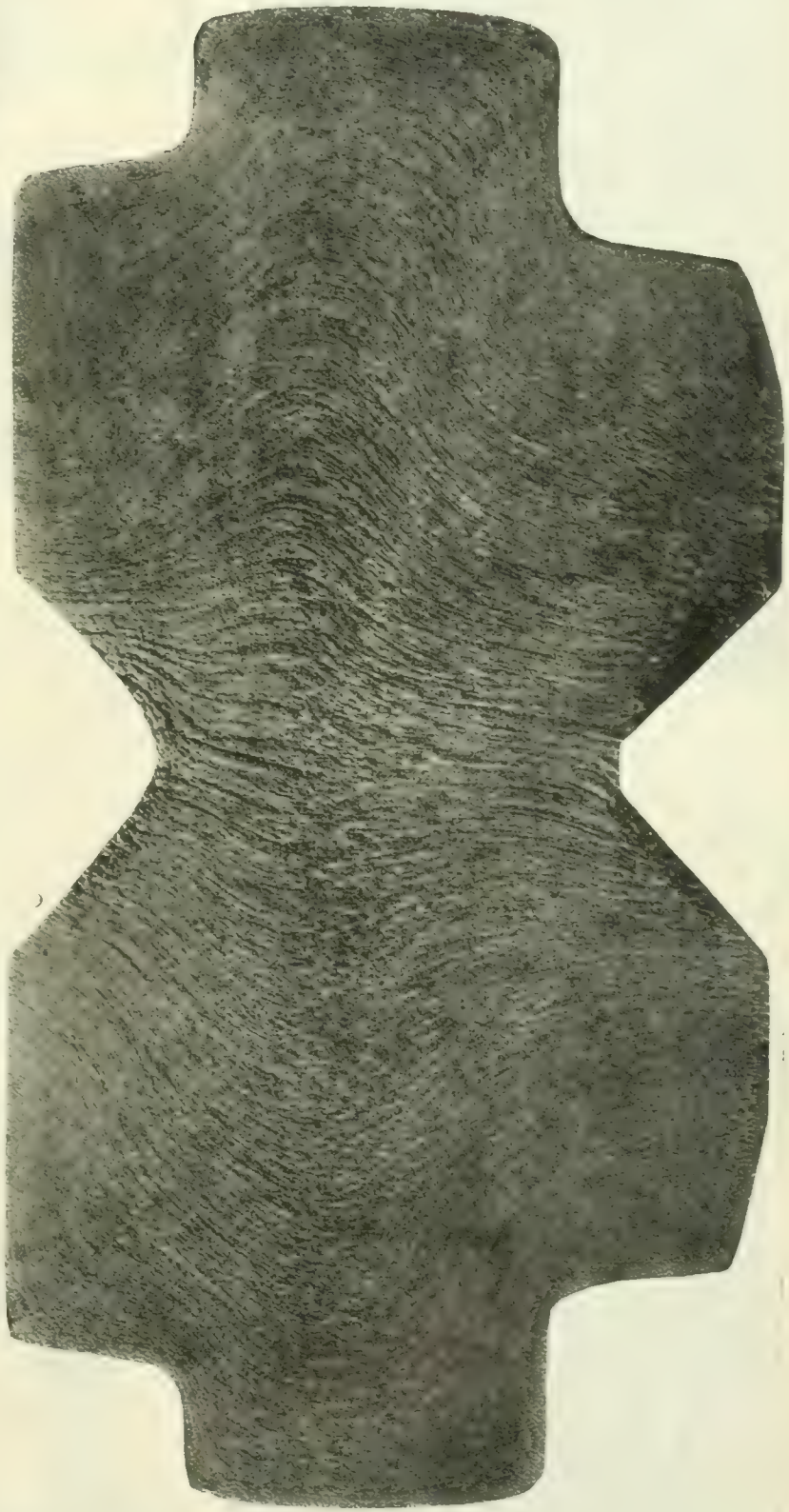
In the enlarged section the grain flow of the metal is from the center, the fibres being bent back upon themselves, and in the finished gear are at all points perpendicular to the forces applied to the gear teeth.

The section of gear shown is not the result of an ordinary upset operation, yet has all the desirable advantages of such method, with the added feature of extreme refinement of the tooth portion around the entire periphery.

Also in the use of this method it has been found that it is not necessary to require as high temperatures to forge as for the old-fashioned procedure.

In final heat treatment of the finished gears less distortion results. Comparative tests show that the weakest teeth by our improved method of forging are twice as strong as the weakest teeth of former ways of forging blanks.

In other words, our customers are receiving twice as much strength combined with increased uniformity than heretofore. All we ask is an investigation, and you, too, will be convinced to use gear blanks produced by our improved method of forging.



MADE BY

CANTON DROP FORGING & MFG. COMPANY, CANTON, OHIO

Why "DOT SERVICE

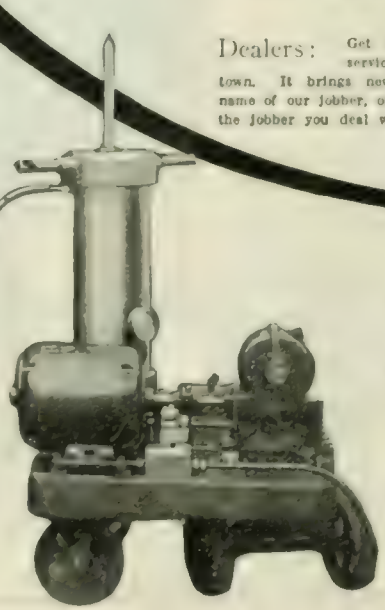
ADOPTED
As
Standard Equipment
By
69 Manufacturers
of
Cars, Trucks and Tractors

Manufacturers who endeavor to build longer and more dependable service into their cars, trucks and tractors, will be interested in the DOT and the service it offers.

The DOT System gives thorough *positive* lubrication to the chassis as efficiently as the lubricating system used for the motor. In a few years it has won national recognition and national distribution, solely upon its merits.

Leading engineers who have tested it are enthusiastic, and 69 manufacturers of cars, trucks and tractors have already adopted it as standard equipment. It has been tested and adopted by the U. S. War Department and is used as lubricating equipment for industrial machinery in more than 100 leading American industries.

Motor-Driven Portable Tank



CARR FASTENER COMPANY
31 Ames Street Cambridge, Mass.

Dealers: Get the "Handy Service Kit" and give service to the many DOT Owners in your town. It brings new business. Let us send you the name of our jobber, or if you prefer, send us the name of the jobber you deal with.

Exclusive DOT Features

1—*Progressive* pressure from 1 to 3,000 pounds. Forces out *spent* grease and forces in fresh lubricant.

2—Direct connection—no tubes. Can be operated entirely with one hand.

3—Automatic valve retains lubricant without turning back handle to relieve pressure. Cannot leak. Handles oil as well as grease or kerosene for flushing bearing.

4—Sturdy steel nipples bring all parts within easy reach. Bronze nipples for marine use.

5—Lubricates entire chassis in 13 minutes or less. (Fords in six minutes.)

The DOT Lubricator is thoroughly protected by allowed claims of pending patent applications

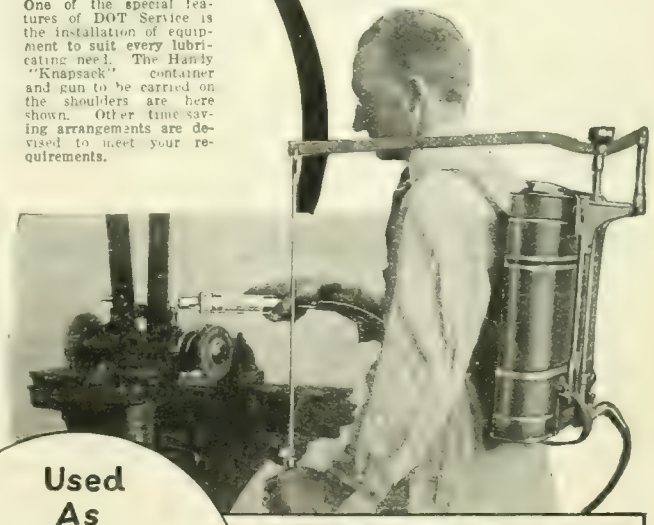
DOTS THE MAP

The above map shows the distributing centers of the DOT. Leading jobbers and distributors—strategically located in the largest cities in America—cover every trading area, securing DOT Sales and Service through their thousands of dealers everywhere.

Manufacturers who have standardized on the DOT System, motorists and fleet owners who have installed it, are, therefore, assured of efficient service and easily available supplies.

Special DOT representatives are always within easy reach to help you solve your lubricating problems either in the automotive or industrial field. An interview may save you costly losses in depreciation, repairs and production delays, which may be due entirely to faulty methods of lubrication.

One of the special features of DOT Service is the installation of equipment to suit every lubricating need. The Handy "Knapsack" container and gun to be carried on the shoulders are here shown. Other time-saving arrangements are devised to meet your requirements.



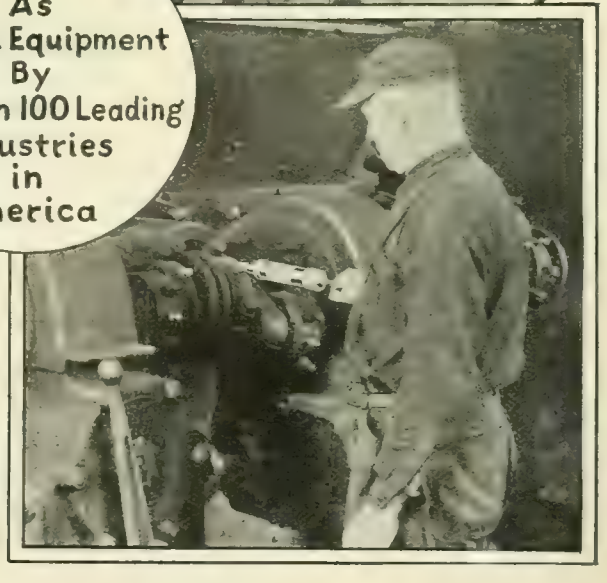
"MAKERS OF THE 'DOT' LINE OF FASTENERS"

Used by more than 90% of the automobile manufacturers in America and the majority of manufacturers abroad.

Branch Offices:

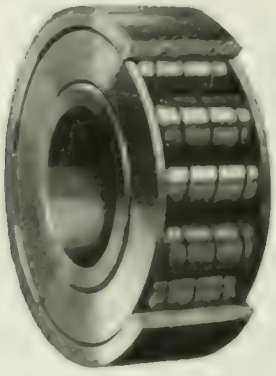
40 Selden Ave. Detroit — 47 W. 34th St. New York City — Monadnock Bldg. San Francisco — Gage Ave. & Beach St. Hamilton, Ont., Canada

Used As Standard Equipment By More than 100 Leading Industries in America



The DOT high pressure LUBRICATOR

Write Today for These Three Bulletins on the Hyatt New Series Roller Bearing



Every automotive executive, engineer and draftsman should have in his possession copies of these three bulletins on the Hyatt New Series Bearing. This conveniently bound information is practically indispensable for those responsible for bearing applications.

The bulletins consist of "Data Sheets on Bearings for Motor Cars and Trucks"—"Design Sheets on Transmissions for Passenger Cars"—"Design Sheets on Axles for Passenger Cars."

These three bulletins will be gladly forwarded upon request. In order to have your data files complete, write for these bulletins today.

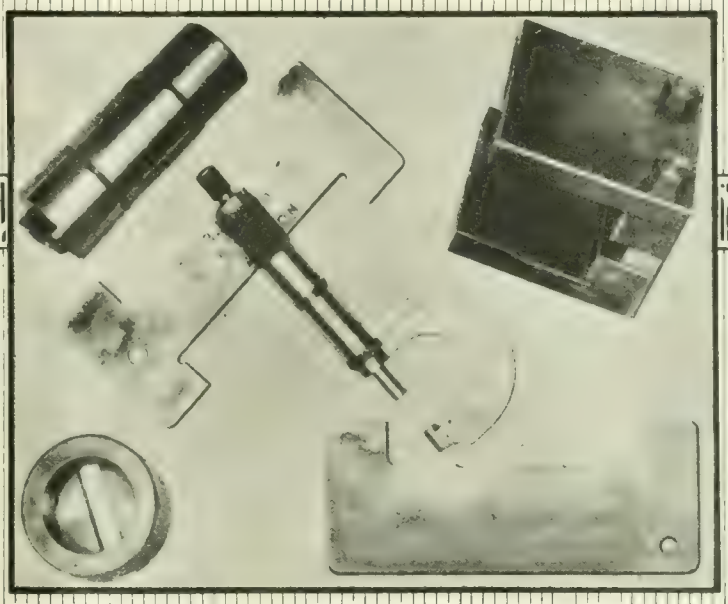
HYATT ROLLER BEARING COMPANY

Newark Detroit Chicago San Francisco
Worcester Milwaukee Huntington, W. Va. Minneapolis Philadelphia
Cleveland Pittsburgh Buffalo Indianapolis

HYATT

Quiet

Roller Bearings



Get them right the first time

Namco

Screw products

Protect Your Schedules

Suppose the above hardened and ground, close tolerance job is yours. You have output schedules to meet. The parts come in on the date promised and go to your assembly. In rushes one of your inspectors—and somewhere down the line of manufacture something has happened.

Of course, the maker will replace the part if he is wrong, he will make the job over in part or whole, he will allow you credit—anything to make good. But whatever he does, if the parts were not right the first time, then both you and he are in for a loss, your manufacturing schedule is upset and you are out of luck.

Whether simple or complex, your milled parts should be made by specialized methods interpreted by men who know your requirements. Of such is NAMCO Service made up. Send samples up to 4" and we will prove it.

The National Acme Co.

CLEVELAND, O.

NEW YORK ▾ CHICAGO ▾ DETROIT ▾ BUFFALO ▾ BOSTON

23065

Every Driver Desires Easy Steering

Owner satisfaction depends in very great measure on the physical effort required to handle the car. The only point of constant application of physical effort is the steering wheel. The easier the car steers, the less physical effort, and logically increased pleasure in driving.

The easy steering and the powerful and easy control provided under all road conditions by the new Ross cam and lever steering gear arouses the keenest enthusiasm on the part of every driver. In straight-away driving, the gear is so irreversible that practically all road shock is eliminated. In turning, the variable pitch of the cam develops a unique accelerated action which facilitates quick and easy control —a feature which appeals to every driver when backing into flat-to-the-curb parking position.

Every motor car manufacturer who is interested in increasing owner satisfaction should investigate the easy steering of this new gear. Full information on request.

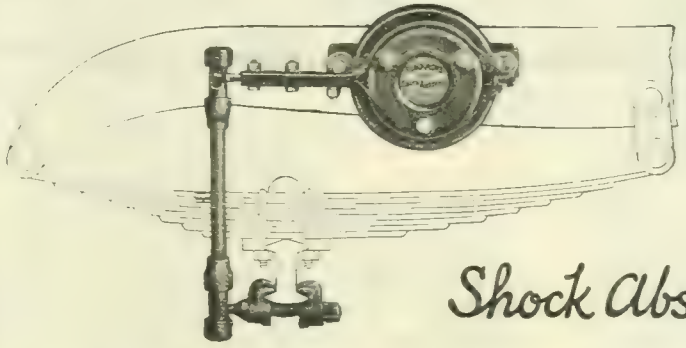
Steering Gears
for
Passenger Cars
Motor Buses
Motor Trucks
Fire Trucks
and
Tractors

ROSS GEAR & TOOL COMPANY
730 Heath St. Lafayette, Indiana, U.S.A.

ROSS STEERING GEARS

POWER ~ SAFETY ~ RELIABILITY — and EASY STEERING

Triple-Acting Blackmore



Shock Absorber

A *Shock Absorber* that does *Not* Stiffen the Springs

Most Engineers agree that the ideal method of securing ease of riding is to control the energy of compression as well as to check rebound as this is the *only way* of taking the peak off *both ends* of the spring vibration.

A wave-like motion imparted to the body gives maximum comfort. This result cannot be secured by any one-way rebound checking device as the peak or jolt of compression is often as disagreeable as the rebound.

Heretofore all devices that checked compression had a decided stiffening effect on the flexing of the spring, but *now for the first time since the beginning of the industry* a simple strong and efficient device has been perfected that by an entirely new principle:

FIRST: Softens the springs on small bumps.

SECOND: After passing the period of softening action automatically changes into an increasing frictional resistance to further compression, thereby *preventing some of the forces of rebound being stored in the spring.*

THIRD: On the rebound they again automatically change into the best method of checking the rebound forces still left in the springs.

The Blackmore Triple Acting Shock Absorbers do these three things, and therefore *give a superior result to that offered by any device that only acts on rebound forces.*

Four wheel brakes are now considered necessary for a modern car. Bumpers, windshield wings, trunks, special tops and paint are also considered necessary on many sport models. The riding public is also demanding greater comfort, which cannot be secured by uncontrolled longer springs or by devices that only check rebound. We offer you an opportunity to experiment with the newest and most improved device for easy riding, so you can provide this comfort to your future owners. An ideal device for use with balloon tires.

THE CHARLES C. BLACKMORE COMPANY

1017 East Fifth Street, Dayton, Ohio

A. M. DURLEY
Manager Engineering

At the Automobile Shows

Engineers and other interested Officials of the Automotive Industry are cordially invited to visit Westinghouse Headquarters during Automobile Show week, where, available for inspection, will be found Starting, Lighting and Ignition Apparatus embodying many new developments and innovations.

Remember the Place

NEW YORK
Hotel Biltmore
Jan. 5 - Jan. 12

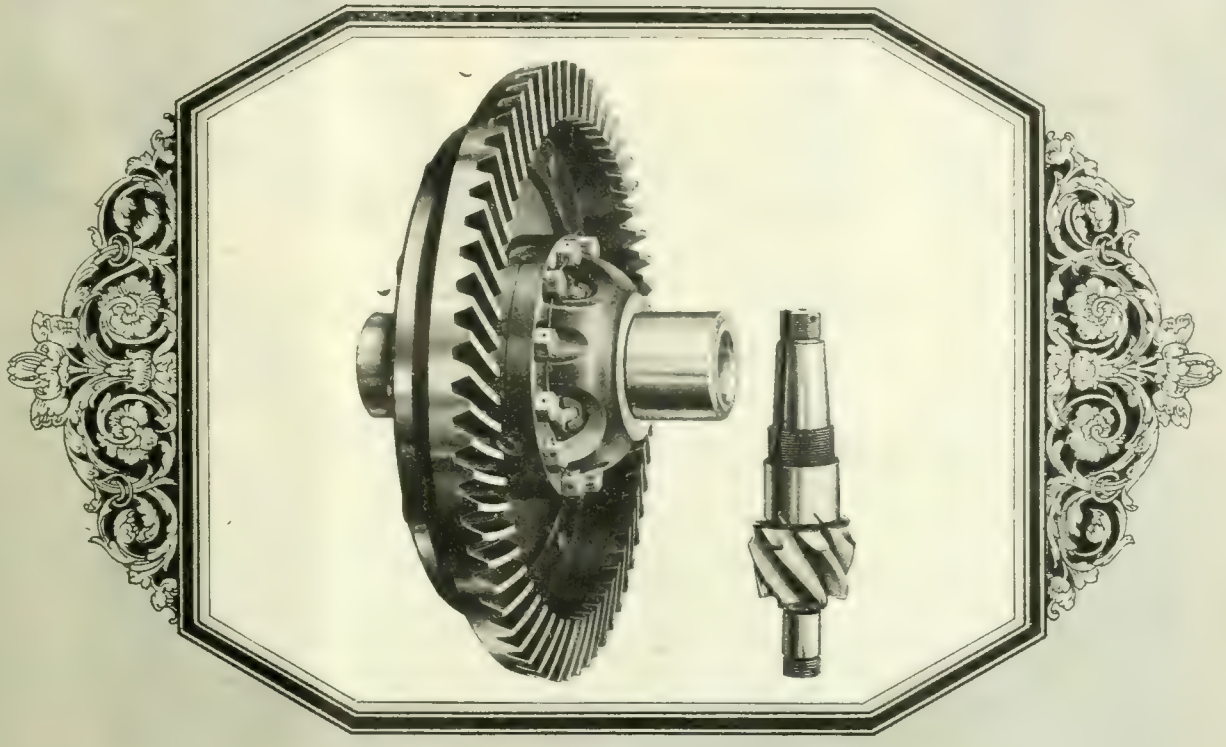
CHICAGO
Hotel Congress
Jan. 26 - Feb. 2

B. D. KNEE
Superintendent in Charge of Manufacturing

W. A. DICK
Commercial Engineer

T. A. COUSINS
Assistant Sales Representative, Detroit

Westinghouse



MOST of the successful motor car and truck manufacturers are known to be discriminating in the extreme, when selecting those units which they purchase outside their factories. As an interesting coincidence: Brown-Lipe-Chapin products almost invariably appear in their specifications.

Manufactured at Syracuse, N. Y.

BROWN-LIPE-CHAPIN

DIFFERENTIALS — BEVEL DRIVE GEARS

Prest-

Battery FOR CARS

The extent to which Prest-O-Lite batteries are used as original equipment in automobiles is partly due to the reputation which this organization has built up through years of honest dealings with the public—partly due to satisfaction which a good battery can add to ownership of any car—and partly due to the immense facilities of this organization for giving service to the manufacturers who use its products. All these are reasons which any manufacturer should consider favorably in choosing equipment for his car.

THE PREST-O-LITE COMPANY, Inc., *Indianapolis, Indiana*

New York Office: 30 East 42nd Street Pacific Coast Office: 599 Eighth Street, San Francisco

In Canada: Prest-O-Lite Company of Canada, Ltd., Toronto

O-Lite

Gas FOR TRUCKS

The very fact that there are over 22,000 places where truck drivers can exchange Prest-O-Lite gas tanks for empty ones, paying only for the gas, shows the popularity of Prest-O-Lite gas with truck owners.

When a product has such wide-spread approval from the public which you serve—plus the added distinction of being "the oldest service to motorists"——why not consider its adoption for the trucks which you design or build?

THE PREST-O-LITE COMPANY, Inc., *Indianapolis, Indiana*

SMALL TANK SALES DEPARTMENT

New York Office: 30 East 42nd Street Pacific Coast Office: 599 Eighth Street, San Francisco

In Canada: Prest-O-Lite Company of Canada, Ltd., Toronto

Worn Out—Just rubbed in air

A flash of fire strikes the night sky and is gone. Where?

Swallowed by Friction. Literally burned to nothingness, actually worn out of existence, simply by rubbing the air.

That's a "shooting star" to us. A mass of mostly mineral substance, flung from some whirling body of the skies, hurtling through the airless voids of the universe, until it happens to fly into the layer of air which surrounds our earth.

Just rubbing the atmosphere kindles the blazing ball you see, the "shooting star." The friction of just moving through the air is what utterly consumes it.

Anything which moves, however fast or slowly, even in the thin invisible air, or on finest lubricating oils, is inevitably subject to the wear of *motion*.

It is motion, as you know, which wears your motor car. How long your automobile will last, how smooth-running and quiet you can keep it, depends then upon how well you are permitted to compensate for the wear that *must* follow motion.

You are sure there *will be* wear from motion. To enable you to offset the chief effects of this certain wear, make sure the principal revolving parts are mounted on bearings which can be adjusted. The basic principle of anti-friction bearing adjustability is embodied in Timken Tapered Roller Bearings. THE TIMKEN ROLLER BEARING CO., *CANTON, OHIO.*

TIMKEN
Tapered
ROLLER BEARINGS

Made by The Timken Roller Bearing Co., Canton, O.

Objections which have been made—either justly or unjustly—to mechanical four wheel brakes, do not apply to hydraulic four wheel brakes.

It has been asserted, for instance, that the only two claims made for four wheel brakes are, that they permit quicker stopping and prevent skidding.

Beside accomplishing these two vitally important results, Lockheed Hydraulic Four Wheel Brakes also—

Require practically no adjustment, being from the very nature of the hydraulic principle always perfectly equalized. (At very long intervals it is necessary to "take up" on the brake bands because of wear on the brake lining.)

Because pressure is always equally distributed to the four brakes, the brake lining used in connection with Lockheed Hydraulic Four Wheel Brakes lasts about four times as long as when used with two wheel mechanical brakes.

In descending long grades, four wheel brakes remove fear of the car getting away—a fear that is always present when two wheel brakes are the braking equipment. Furthermore, four wheel brakes make it unnecessary to use the motor as a brake.

Because they never drag, they afford greater gasoline mileage.

Again, it has been objected that mechanical four wheel brakes increase the expense of maintenance. With hydraulic four wheel brakes, the expense is less than with two wheel mechanical brakes.

Mechanical four wheel brakes, say some opponents, require greater power to operate the brakes and to steer the car.

Hydraulic four wheel brakes require less foot pressure than mechanical two wheel brakes.

A car equipped with hydraulic four wheel brakes steers just as easily under all conditions as a car equipped with two wheel mechanical brakes.

Other objections which have been made to mechanical four wheel brakes fail just as completely as those above mentioned, when confronted with the actual results which Lockheed Hydraulic Four Wheel Brakes have proved in the hands of hundreds of owners.

Leading cars, which will soon announce Lockheed Hydraulic Four Wheel Brakes as standard equipment, will quickly demonstrate to the whole American public that these hydraulic brakes are unapproached in every phase of performance.

Hydraulic Brake Company
5833 Russell Street, Detroit, Michigan

LOCKHEED

Hydraulic Four Wheel Brakes

The Explosive Action

of the Bowen-Empress Gun shoots a charge of the lubricant into the bearing under high pressure, driving out the dirt, grit and old dead grease, leaving the bearing completely covered with a film of fresh, clean lubricant.

Before applying the Bowen-Empress Gun to the fitting on the bearing, pressure is first developed in the gun by turning the plunger forcibly against the lubricant. A check valve in the nozzle holds the pressure within.

Next, using one hand only, the connection cover is lifted with the slotted gun end and the nozzle thrust into the connection, the valve in the nozzle coming in contact with the trip in the bottom of the connection, releasing the pressure and instantaneously flooding the bearing with a charge of the lubricant. The dust tight connection cover is then snapped shut, using the gun end. Then withdraw the gun and develop the pressure for the next bearing.

Quick, Clean and Convenient. No connections to make between gun and fitting. No easily mislaid dust caps to remove and replace. No dirt collecting open ball check fittings. No flexible hose to break under pressure. Unnecessary to lock gun to fitting on bearing or to turn back plunger to relieve pressure before removing gun from fitting on bearing.

The Bowen-Empress System can be used with either oil or grease as the lubricant.

Bowen Products Corporation

Auburn Division, Auburn, N. Y.

Write for Descriptive Booklet No. N 301

One Hand Operates It.

Bowen-Empress

HIGH PRESSURE LUBRICATING SYSTEM

FOR ALL MOTOR CARS AND TRUCKS

Strom Service Department, Home Office, Chicago

The Golden Rule in Business

We give the kind of service we like to get

Strom service is as good as we know how to make it. We have studied what manufacturers need. And we have adapted our service to their needs.

On orders for ball bearings from stock we can frequently make shipments the same day the order is received.

Where technical advice is needed, our corps of experts is at your service. They are familiar with every type of ball bearing installation ever made. We will be pleased if you will call on us.

Our interest in our installations continues long after we have made delivery. We are concerned with the successful operation of our bearings throughout their lives.

We believe in the golden rule in business. We give the kind of service that we like to get.

Double-acting thrust bearing, flat seats (grooved races) 2100-F Series

Single-acting thrust bearing, flat seats (grooved races) 1100-F Series

Single-acting, self-aligning thrust bearing 1100 Series

Single-acting, self-aligning thrust bearing, leveling washer, 1100-U Series

Double-acting, self-aligning thrust bearing, leveling washers 2100-U Series

Single-row deep-groove Standard type, radial bearing

Double-row, deep-groove Standard type, radial bearing

Angular contact bearing combination radial and thrust

Double-row, [illegible] type radial bearing

Single-row, maximum type, radial bearing

Strom BALL BEARINGS

"Wherever a Shaft Turns"

U. S. BALL BEARING MFG. CO.

4533 Palmer Street, Chicago, Ill.

AGATHON ALLOY STEELS

IMAGINE, if you can, the automotive industry without alloy steels. Think of the greatly increased bulk and weight that would necessarily have to be added to the cars of today. Think of the added cost of upkeep—the frequency of breakage—the added dangers of traveling at high speed.

Truly, alloy steels form the backbone of all that has been accomplished in the automotive industry in producing cars of greater speed, greater endurance, greater safety and greater comfort. In fact, many car builders have come to depend so heavily upon alloy steels that from seventy to eighty parts which are subjected to greatest stress and wear are made of these super-steels.

While all of our alloy steels are made under the "Agathon" trade name they embody various analyses, particularly suited to Axle Construction, Differential Frame, Front Axle, Motor Parts, Shafts, Transmissions, Springs, Steering Parts, etc. We have an interesting booklet entitled: "Agathon Alloy Steels," describing many of our steels for the automotive industry. Send for a copy.

We have daily production in all kinds of commercial alloy steels such as—

Nickel, Chrome-Nickel, Uma, Molybdenum, Chrome-Molybdenum, Nickel-Molybdenum, Vanadium, Chrome-Vanadium, Chromium, etc.

Deliveries in Blooms, Billets, Slabs, Bars, Spring Flats, Hot Rolled Strips, etc.

THE CENTRAL STEEL COMPANY, Massillon, Ohio

SWETLAND BLDG. CLEVELAND | BOOK BLDG. DETROIT | PEOPLES GAS BLDG. CHICAGO | UNIVERSITY BLOCK SYRACUSE | WIDENER BLDG. PHILADELPHIA

Announcing

The New Warner Precision Speedometer

THE last word in speed-recording accuracy. All of the inherent qualities, all of the time-proven features of Stewart, Warner and Van Sicklen instruments are embodied in this one speedometer—the Warner Precision.

From the first turn of the wheels, and at any speed the car may travel, it registers miles per hour with remarkable accuracy. Regardless of the weather conditions, no matter how hot or how cold, this precision of speed indication remains unchanged. Variance in air pressure or humidity has not the least effect upon it.

Absolute quiet in driving operation is attained by means of bakelite, linen gears.

The odometer construction is greatly simplified by unit assemblies.

The improved dial alignment is made possible by a light tension impulse spring.

Sapphire jewels, of the same type used in the balance wheel of a watch, are placed on the speed cup pivots to provide the utmost in bearing suspension.

The satin-like finish of the dial face, the beautifully nickeled flange, the easily-read numerals, give this instrument a de luxe appearance worthy of the finest cars. Complete with driving equipment, $60.00.

STEWART-WARNER SPEEDOMETER CORPORATION - CHICAGO, U. S. A.

Stewart

CUSTOMBILT ACCESSORIES

USED ON 8 MILLION CARS

CHAMPION

There's no factor so fatal to the permanent solution of a perplexing forging problem as the tendency to let price variations sway one away from the source of supply that achieves the solution. And that tendency is rooted in the obsolete belief that one forging can be like another or that all forgings are alike.

Stand steadfast on the concern that solves your forging problems and you will have no occasion to endure back slapping. The Champion organization has demonstrated for the makers of many prominent motor cars an ability to overcome obstacles deemed well nigh insurmountable

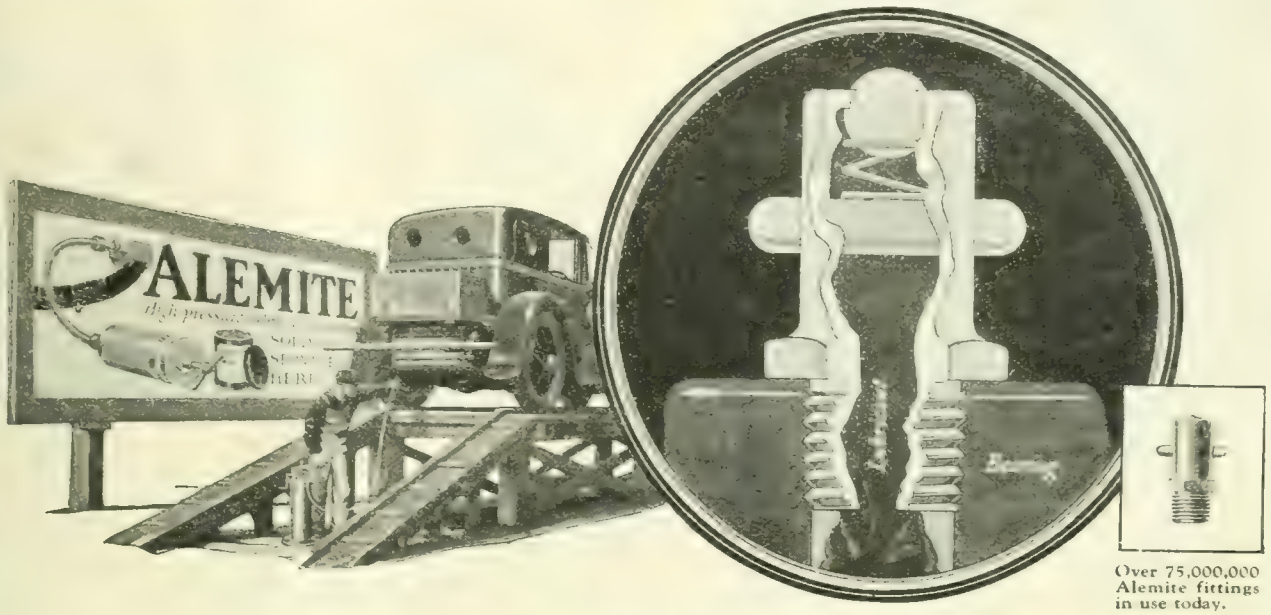
Your problems interest us. By solving them we presume to prove our right to your forging business on the basis that a forging is something more than a piece of hammered steel

The Champion Machine & Forging Co.

3695 East 78th Street, Cleveland, Ohio

New York Office—30 Church St
Philadelphia Office—Bourse Bldg
Detroit Office—705 Ford Bldg

DROP FORGINGS



Over 75,000,000 Alemite fittings in use today.

1303 New ALEMITE Stations in the Month of September

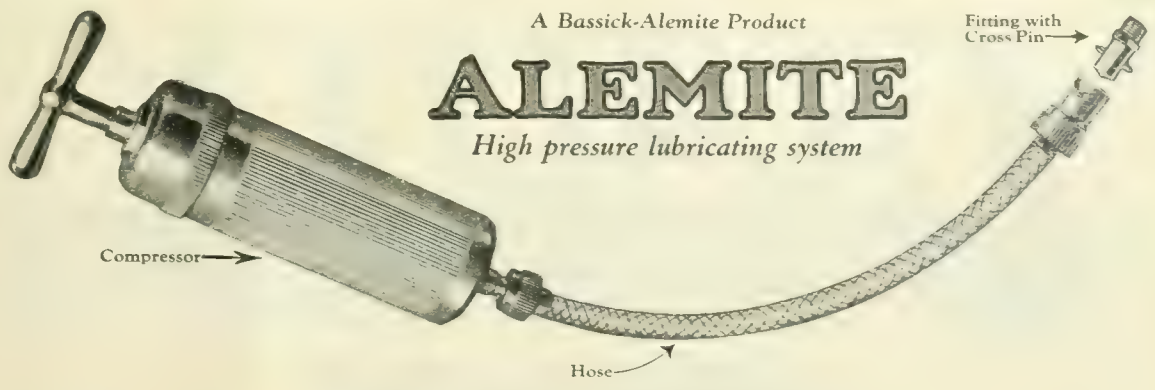
In Pittsburgh alone 61 new places installed Alemite Service Equipment—in 11 days

In the month of September, 1303 *new* Alemite Lubricating Station Outfits were installed the country over.

Think what this means! These stations have capacity to lubricate over 300,000 cars and trucks per month. And this is just *one month's addition* to the huge nation-wide Alemite Service organization—that keeps Alemite-equipped cars well lubricated everywhere.

In Pittsburgh alone 61 new stations installed Alemite Service in 11 days.

The standard Alemite Lubricating System is becoming more and more important due to the increasing patronage given lubricating service stations by car owners everywhere. When you put Alemite on the cars you make, you at once insure your owners of country-wide lubricating service.



A Bassick-Alemite Product

ALEMITE

High pressure lubricating system

The Bassick Manufacturing Company
2654 N. Crawford Avenue - - - Chicago

QUALITY Piston Rings are carefully wrapped in waxed paper and packed in this grey and royal purple box.

STANDARD OF THE INDUSTRY

MORE than one hundred leading manufacturers of internal combustion engines specify **QUALITY** piston rings for original installation—because they are accurate, quick seating, long lived and easy to install.

More than two hundred discriminating distributors choose **QUALITY** rings because they strive to give their dealers the utmost in QUALITY–SERVICE–PRICE.

Thousands of dealers handle **QUALITY** rings for resale because giving the public what it wants—means low sales resistance with a resultant quick turnover.

The Piston Ring Company

Muskegon, Michigan

QUALITY
Piston Rings

"CAST TO LAST"

Think Of The Strains And Sudden Shocks

to which gears, particularly those in the transmission, are subjected.

Even in the light car, gears are put to severe test. And in the heavy truck, the service virtually amounts to abuse.

The best safeguard against broken gear teeth and stripping is the use of better steel — Vanadium Steel.

Strength, hardness, toughness, wear resisting and anti-fatigue properties—all these gear steel essentials are present in a high degree in Vanadium Steel.

Write for data on the use of Vanadium Steel in gears.

VANADIUM CORPORATION OF AMERICA

NEW YORK
120 Broadway

DETROIT
Book Bldg.

VANADIUM STEELS

for Strength, Toughness and Durability

You get more pieces per pound — and you buy less pounds — when

MUELLER
***Forges* Brass**

The greater strength of Mueller Brass Forgings means lighter weight parts for the same sturdy service.

Mueller Forges Brass

Forged under 400,000 pounds pressure while at a cherry red heat, sand holes and other flaws become impossible in Mueller Brass Forgings.

Brass sand castings develop 10% to 15% scrap, in the foundry and at your machines.

You can save this loss by using Mueller Brass Forgings.

MUELLER METALS CO., PORT HURON, MICH.

Sales Offices: New York, Philadelphia, Buffalo, Pittsburgh, Cleveland, Dayton, Detroit, Indianapolis, Chicago, Minneapolis, New Orleans, San Francisco.

Makers of "Red Tip" Brass Rod; Welding Rod; Brass and Copper Tubing; Forgings and Castings in Brass and Bronze, also Brass Screw Machined Products.

Associated with H. Mueller Manufacturing Co., Decatur, Ill., and H. Mueller Mfg. Co., Ltd., Sarnia, Ont. Makers of Water, Plumbing and Gas Brass Goods and Tools.

© 1927 H MM Co

MORSE CHAIN DOMINANCE

Read Again the List of the Cars Which Use Morse Chains in Their Front End Drive

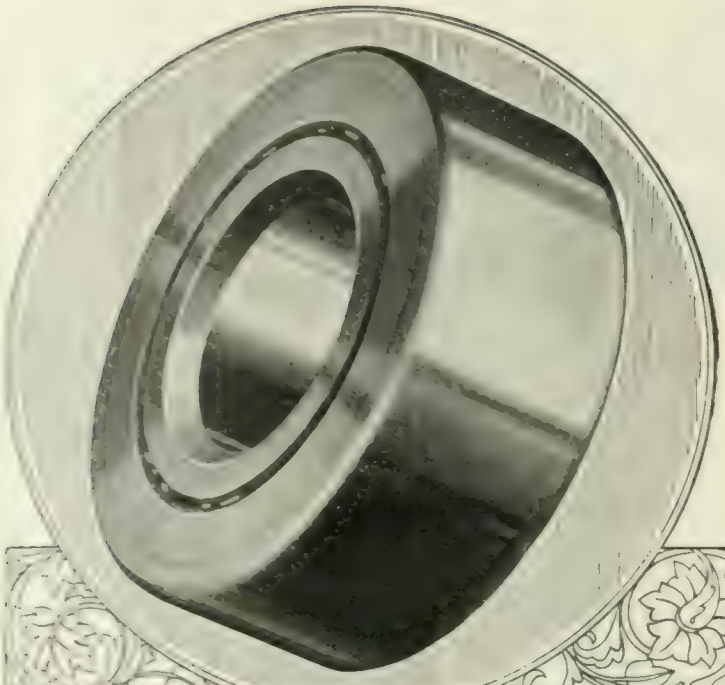
Anderson Six
Auburn Six
Barley Six
Cadillac Eight
Case Six
Chalmers Six
Chandler Six
Cleveland Six
Columbia Six
Crawford Six
Davis Six
Essex Four
Flint Six
Fox Six
Hupmobile Four
Hudson Six
Jordan Six
Lafayette Eight
Lincoln Eight
Moon Six
National Six
Northway Four
Oakland Six
Packard Single Six
Packard Single Eight
Rickenbacker Six
Stearns Four
Stearns Six
Saxon Four
Sterling-Knight Six
Studebaker Light Six
Star Four
Templar Four
Winton Six
Continental Motors

MORSE CHAIN COMPANY
Main Office and Works
ITHACA, NEW YORK
Sales and Engineering Office
DETROIT, MICHIGAN

THE CONSTANT PRESSURE ANGLE CHAIN

MORSE

GENUINE SILENT CHAIN



New Departure Ball Bearings

Why Ball Bearings, Anyway?

Depreciation in automobiles and trucks is largely a matter of parts wearing loose, with consequent lost motion and an imperfect functioning of one component in relation to another.

There are at least 29 vital points where moving shafts and gears depend upon anti-friction bearings for support. It is not so much the wear of the bearings themselves as the letting down and throwing out of alignment and adjustment of these shafts and gears. The replacement or "taking-up" of bearings does not help, because the damage is already done. To keep a vehicle "tight" you must never let it get "loose."

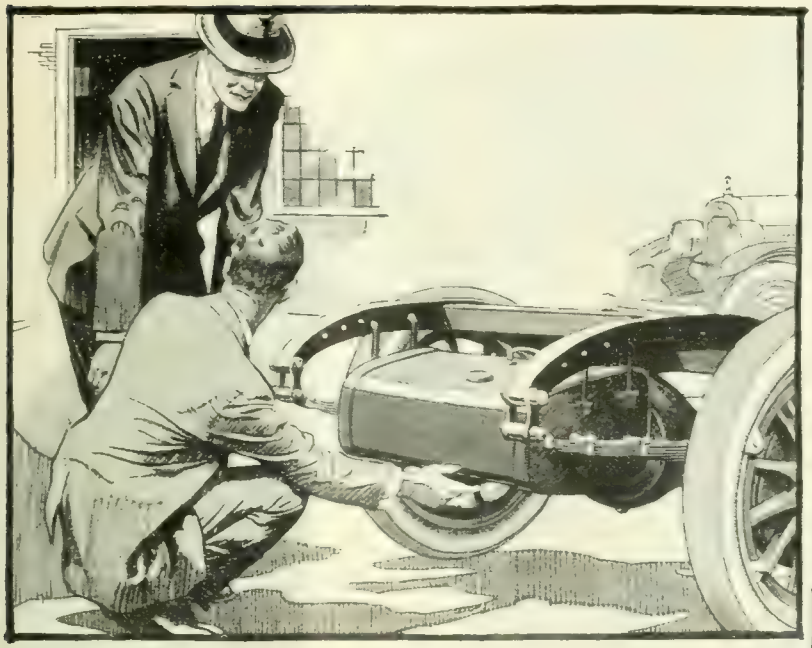
That is why New Departure ball bearings are needed. By very principle, design and materials New Departures do not wear perceptibly, and, barring accident or the entrance of abrasive material, need never be replaced.

Because this fact is being realized more and more, the New Departure plants are being called upon to produce the largest volume of quality ball bearings in their history.

THE NEW DEPARTURE MANUFACTURING COMPANY

BRISTOL, CONN.

Chicago Detroit



The sales arguments that count

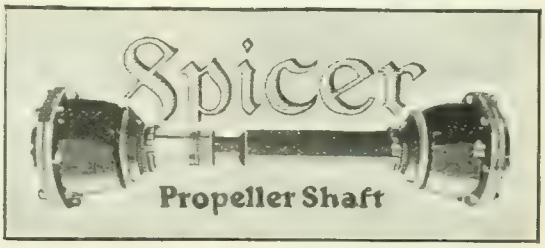
"LOOK at that axle!"—or "that propeller shaft!"—or "that frame!"—or "those springs!"—says the salesman.

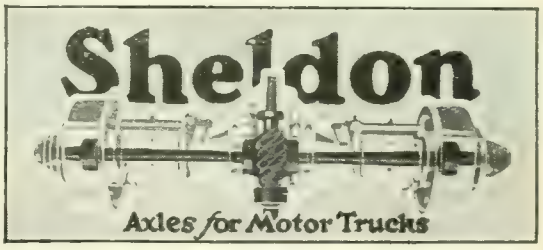
He knows that these—the load-carrying and power-transmitting parts—are the points on which the shrewd purchaser today bases his final decision on which car or truck to buy.

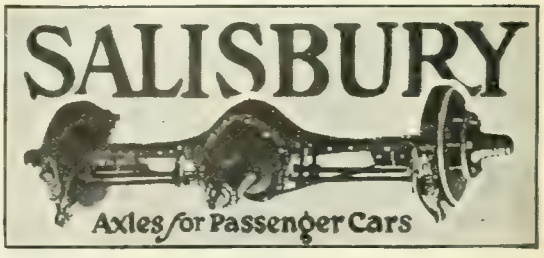
And here's where the names of Spicer, Parish, Sheldon and Salisbury prove their power in closing the sale. Being *known quantities*, the customer accepts them without question.

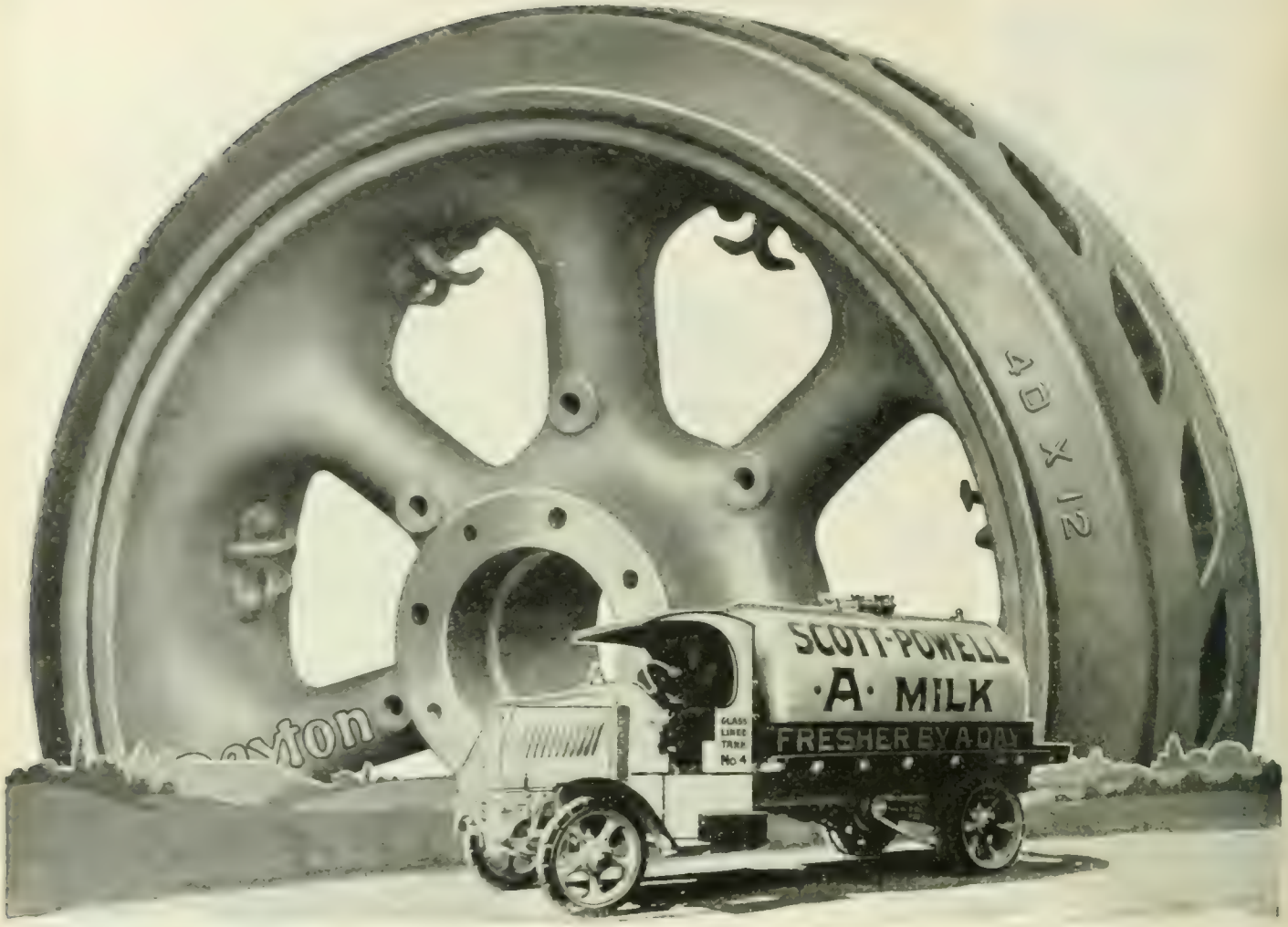
Sheldon Axle and Spring Co. - Wilkes-Barre, Pa.
Parish Mfg. Corp. - - - - Reading, Pa.
Salisbury Axle Co. - - - Jamestown, N. Y.
Spicer Mfg. Corp. - - South Plainfield, N. J.

C. A. DANA, *President*









On the road every day of the year!

EXCUSES don't go in the dairy business. Heavy duty tank trucks must haul thousands of gallons of milk into cities from outlying rural points, every day of the year, no matter the condition of roads.

Many of these trucks carry their daily tanks of milk from dairy farms over a hundred miles distant from the city.

It is a significant fact that nearly all tank trucks of leading makes are equipped with Dayton Steel Wheels.

By the service they are rendering in the dairy business, Dayton Steel Wheels again prove that they are equal to meet, every day in the year, the most trying tasks of load and road.

Perhaps your haulage job is even more exacting than that of the dairy business. Whatever your particular requirements may be, Dayton durability and economy are worth investigating. Let us show you just what Dayton Steel Wheels will do for you.

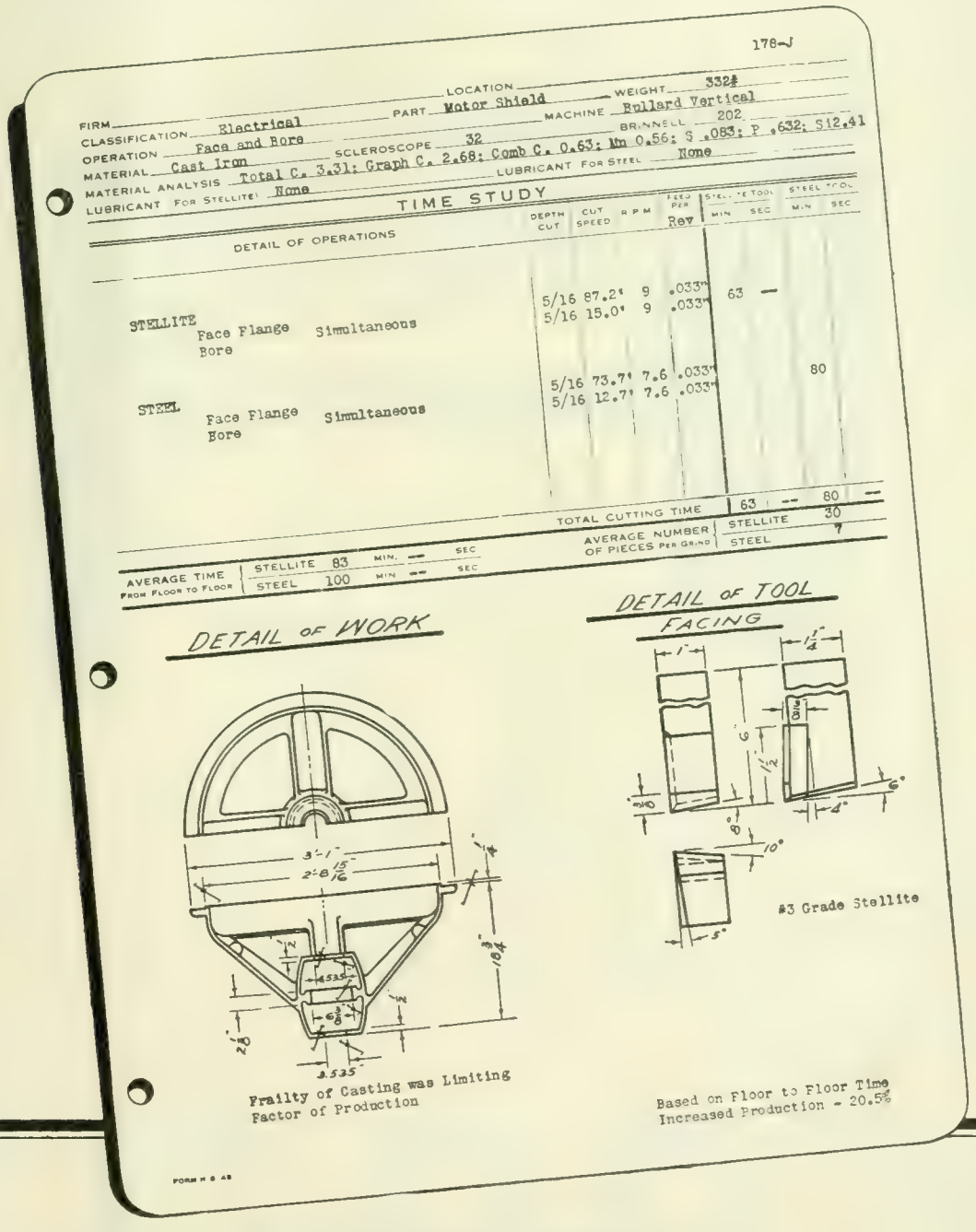
Made for pneumatic and pneumatic tires and for any standard type front or rear axle. Our Engineering Department will co-operate in working out your ideas.

THE DAYTON STEEL FOUNDRY CO., Dayton, Ohio

Dayton
Steel Truck Wheels

HAYNES STELLITE
CUTTING TOOLS

This job was a difficult one owing to the frailty of the casting which necessarily was a limiting factor in production. Haynes Stellite Cutting Tools, however, not only handled it perfectly but increased production 20.5%. The time study shows another interesting fact — how much higher Stellite averaged in number of pieces per grind. Investigate Stellite possibilities on your own work. It will pay you.



178-J

FIRM _____ LOCATION _____
CLASSIFICATION Electrical PART Motor Shield WEIGHT 332#
OPERATION Face and Bore MACHINE Bullard Vertical
MATERIAL Cast Iron SCLEROSCOPE 32 BRINNELL 202
MATERIAL ANALYSIS Total C. 3.31; Graph C. 2.68; Comb C. 0.63; Mn 0.56; S .083; P .632; Si 2.41
LUBRICANT FOR STELLITE None LUBRICANT FOR STEEL None

TIME STUDY

DETAIL OF OPERATIONS	DEPTH CUT	CUT SPEED	R P M	FEED PER Rev	STELLITE TOOL MIN	STELLITE TOOL SEC	STEEL TOOL MIN	STEEL TOOL SEC
STELLITE								
Face Flange Simultaneous	5/16	87.2'	9	.033"	63	—		
Bore	5/16	15.0'	9	.033"				
STEEL								
Face Flange Simultaneous	5/16	73.7'	7.6	.033"			80	
Bore	5/16	12.7'	7.6	.033"				
TOTAL CUTTING TIME					63	—	80	—

AVERAGE TIME FROM FLOOR TO FLOOR: STELLITE 83 MIN. — SEC; STEEL 100 MIN — SEC

AVERAGE NUMBER OF PIECES PER GRIND: STELLITE 30; STEEL 7

DETAIL OF WORK

Frailty of Casting was Limiting Factor of Production

DETAIL OF TOOL FACING

#3 Grade Stellite

Based on Floor to Floor Time Increased Production - 20.5%

FORM H S 48

HAYNES STELLITE COMPANY

Carbide & Carbon Bldg., 30 East 42nd St., New York, N. Y.

Peoples Gas Bldg., Chicago · General Motors Bldg., Detroit · 4503 Euclid Ave., Cleveland

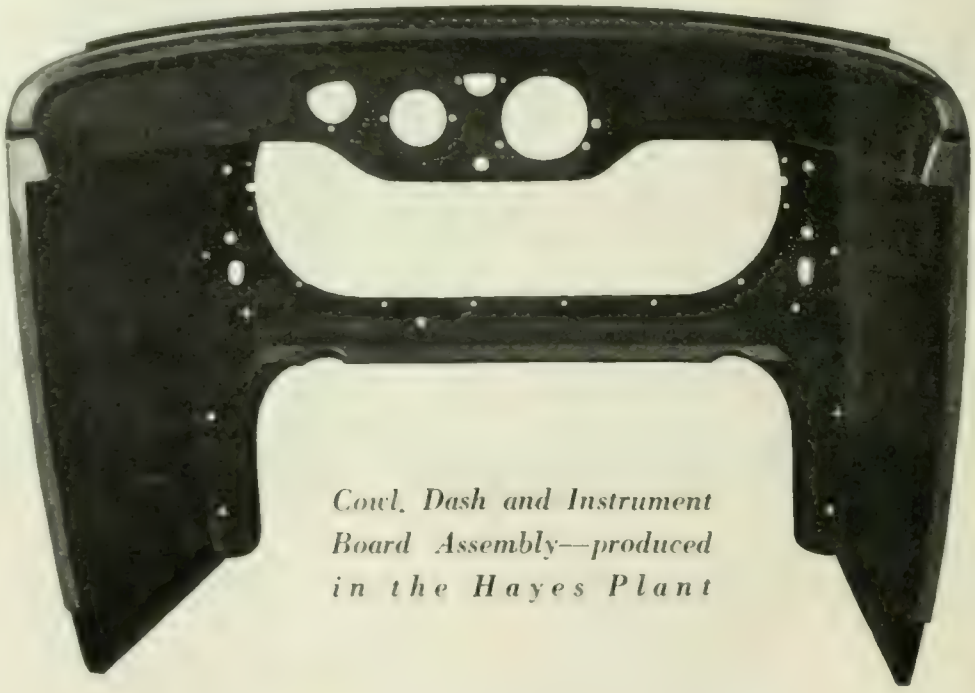
You See

Every Day

HAYES MFG. CO.
HAYES
DETROIT, MICH.

Every-where

Sheet Metal Products



Cowl, Dash and Instrument Board Assembly—produced in the Hayes Plant

EACH year the Automotive Industry achieves new refinements in the building of fine automobiles. In line with the industry's constant striving for improvement in product Hayes Manufacturing Company specializes in the production of superior Automobile Body Stampings and other sheet metal parts.

Here in this splendidly equipped plant Hayes designs and builds its own dies. Instead of manufacturing Cowls out of three pieces of metal, which later must be assembled, Hayes usually stamps the cowl out of one piece. We often fabricate Rear Seat Center Panels, Side Panels and Wheel Housings from one piece of metal, an assembly which usually has been built up from five pieces.

Thus the Automobile Industry looks to Hayes for a superior product. And Hayes' working policy is that only the best is good enough for their customers.

Hayes Manufacturing Company

DETROIT, MICH.

When the Need is for Dependable Screws

Engineers and buyers of long experience now realize that cap screws made by the "upset" or cold headed process must be heat-treated to insure the greatest tensile and ductile strength in the finished product.

That is why they specify Ferry Heat-Treated Screws. They know without experimenting that these screws will give the kind of service they demand.

Whether it be connecting rod bolt, cap screw or special part, they are always sure of their micrometer accuracy, unvarying uniformity and rugged strength. You too can do away with costly experimenting by buying Ferry Process Screws — send us your blue prints and let us quote you our prices; we know they will interest you.

"IF IT'S UPSET—IT MUST BE HEAT-TREATED"

THE FERRY CAP & SET SCREW COMPANY Cleveland, Ohio

FERRY

PROCESS SCREWS

Auto-Lite

Starting, Lighting & Ignition

WITH the names of the more popular motor cars that have won a market clear around the world is linked the name of Auto-Lite. The tie that binds leading automobiles and Auto-Lite together in the esteem of owners is the natural relation of quality and quality, dependability and dependability.

Not alone in America, but on every continent, Auto-Lite is the accepted standard of excellence. Its very name carries conviction and fosters good will. Car owners at large, millions of them, have given Auto-Lite a leadership without barrier or challenge.

This world-wide opinion of Auto-Lite is plainly visible in sales figures.

The Electric Auto-Lite Company

Office and Works: **Toledo, Ohio**

Klaxon insures your safety from the driver who is tempted to "cut short" as he approaches a "blind" curve.

At Dangerous Turns—

At "blind" curves, where a moment's inattention by the "other fellow" means disaster, you know that Klaxon will always be heard and instantly heeded. It is this dependability that has made Klaxon the choice of more than four million motorists.

"A Good Horn is Safety Insurance
Only Klaxon Quality is Good Enough"

Genuine KLAXON Horns made only by

KLAXON

Company :: Newark, N. J.

THOSE parts manufacturers whose reputations have been built and strengthened through a rigid observance of one standard of quality—the best—are users of nickel steels.

The Parish Manufacturing Corporation, makers of Parish Heat-Treated Frames, use nickel steel. Its inherent strength and resulting capacity for enduring abnormal strains and abusive shocks, assure a product whose quality is a certainty.

THE INTERNATIONAL NICKEL CO.
67 WALL STREET, NEW YORK CITY

Producers also of Malleable Nickel in Sheet, Rod and other commercial forms

INCo NICKEL TRADE MARK

Nickel steel

Photograph of car after it was pulled out of the water and (below) photograph of the Delco-Equipment just after it was taken from the wreck.

Submerged for six months in fifteen feet of water at the bottom of a quarry

THE DAYTON ENGINEERING LABORATORIES CO.
DAYTON, OHIO

GENTLEMEN:

We are writing you relative to the dependability of Delco equipment as brought to our notice recently.

In November 1922, a Hudson 6-40 car disappeared from Rutland, Vermont and was supposed to have been stolen. In May of this year, this car was found in an abandoned quarry two miles south of this place in about fifteen feet of water. The water was being pumped out and the car was found at this level. The job of removing the car was given to us by the insurance company and we afterwards purchased it. The top and upholstery had rotted and we took the chassis and motor down for parts. We took the Delco starter and generator off completely and, after drying out the water in this equipment, connected a storage battery to the terminals and found that the armature responded immediately.

As a matter of curiosity we installed this starter and generator in another Hudson car and found that it worked absolutely perfect in every way.

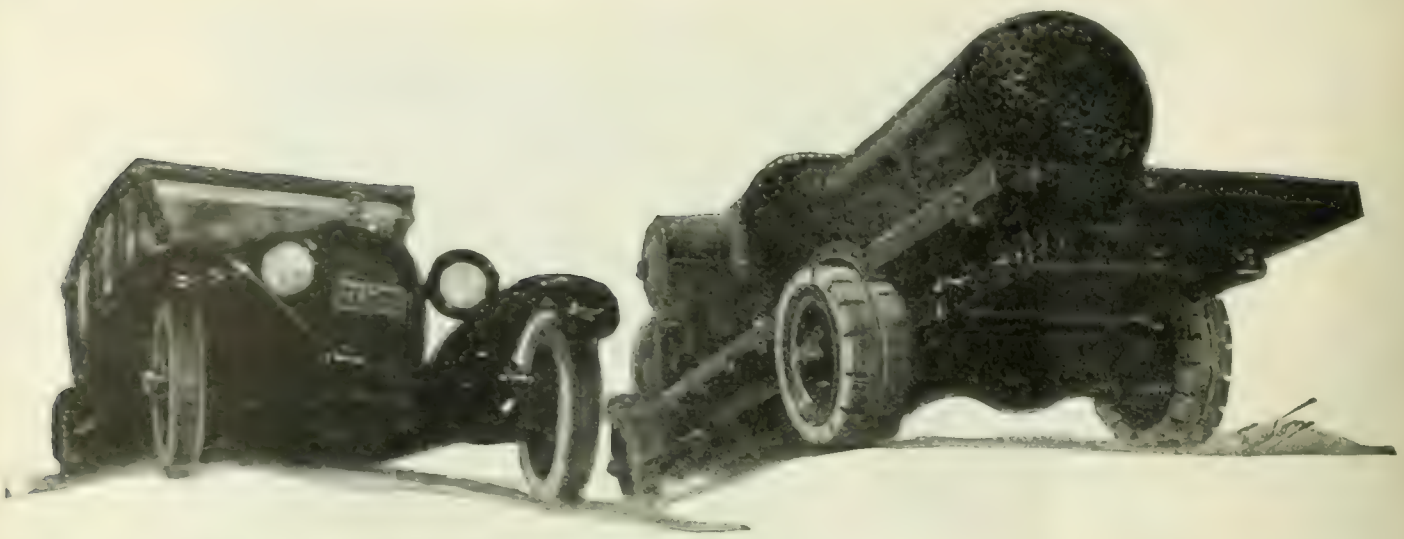
Very truly yours,

H. B. TOWNSEND,
WALLINGFORD, VT.

August 24, 1923

Delco

STARTING, LIGHTING AND IGNITION



ENDURANCE—

The Criterion of All Motor Car Value

The true standard of motor car value is constantly becoming more clearly defined in the public mind. It was first appreciated in the truck—this fundamentally an investment, with endurance standing practically alone to determine the soundness of the buyer's judgment.

But today, in the passenger motor car where this factor not only determines its span of life and resale value, but the comfort, and quietness of its service, the car's foundation is being accorded deserved consideration.

Since the inception of the automobile, when the name of Smith was linked with the first pressed steel frame produced in America, these engineers have been considered authority, and the product of their skill and experience incorporated in any car furnishes a sound basis for confidence in the investment.

Smith frames are the product of the world's largest and best equipped frame plant. The complete laboratories, modern equipment, and engineering departments provide the utmost in dependability and service as a source of supply for even the largest automobile builders.

A. O. SMITH CORPORATION

Milwaukee, Wisconsin

DETROIT OFFICE: 708 FORD BUILDING

BOWER SAVES POWER
BOWER
ROLLER BEARING CO.
Detroit · Michigan
Bower popularity is gaining every day. This without question must be due to the correct fundamental Bower designs and the exclusive Bower features.
Exclusive Bower Features
Separate bearing surfaces for load and thrust. Parallel raceways. Self-aligning. Never need adjusting. Does not develop end thrust under loads. Will not bind or end-slip.
CARRIES the LOAD
TAKES the THRUST

BRONZE Piston Ring Demonstration At REBCO Booth
— New York Automobile Show —

A cordial invitation is extended to Automotive Engineers, Factory Executives, Replacement Parts Dealers, Car Owners and the Public to visit our booth, Space 236, at the New York Automobile Show, Jan. 5 to 12, 1924, for a demonstration of the superior qualities of REBCO BRONZE Piston Rings.

The non-frictional properties of BRONZE Bearing Metal in the manufacture of piston rings and its increased efficiency as compared with cast iron in eliminating heat, producing more power and reducing the wear and tear upon cylinder walls and ring grooves will be strikingly demonstrated.

S. Wilson Morrow, Vice-President and Chief Engineer, and William M. Ives, Sales Manager, will represent this Company at the Show, and will be glad to discuss piston ring performances and problems with visitors.

BOOTH 236

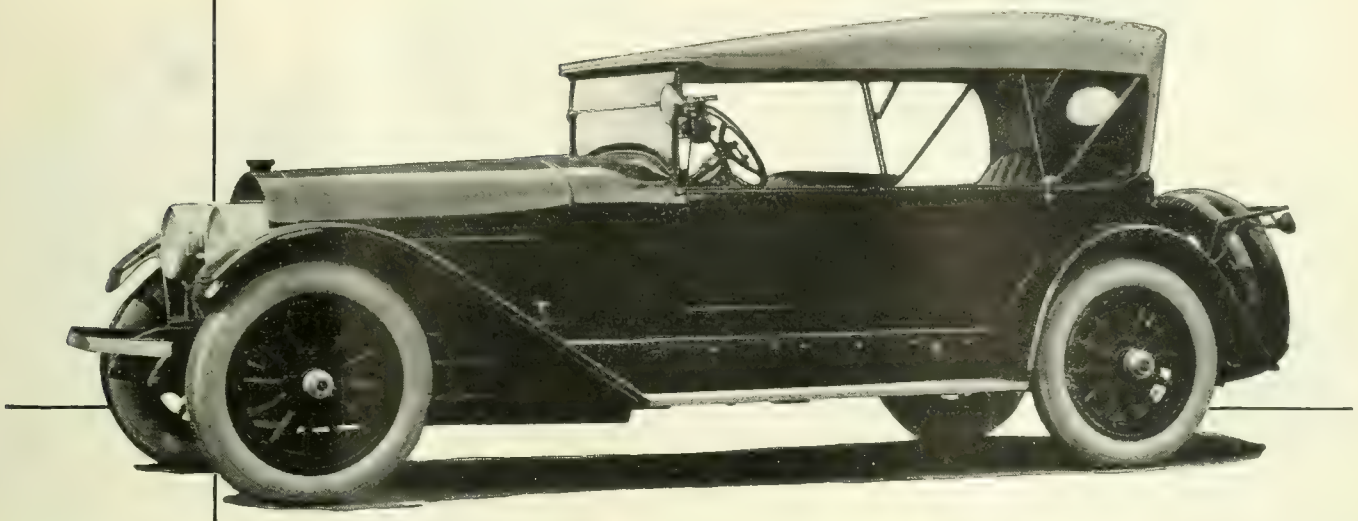
Single REBCO *Dual*

BRONZE Piston Rings

THE REUS MFG. CO.

Fallsway and Eager Street

BALTIMORE MARYLAND

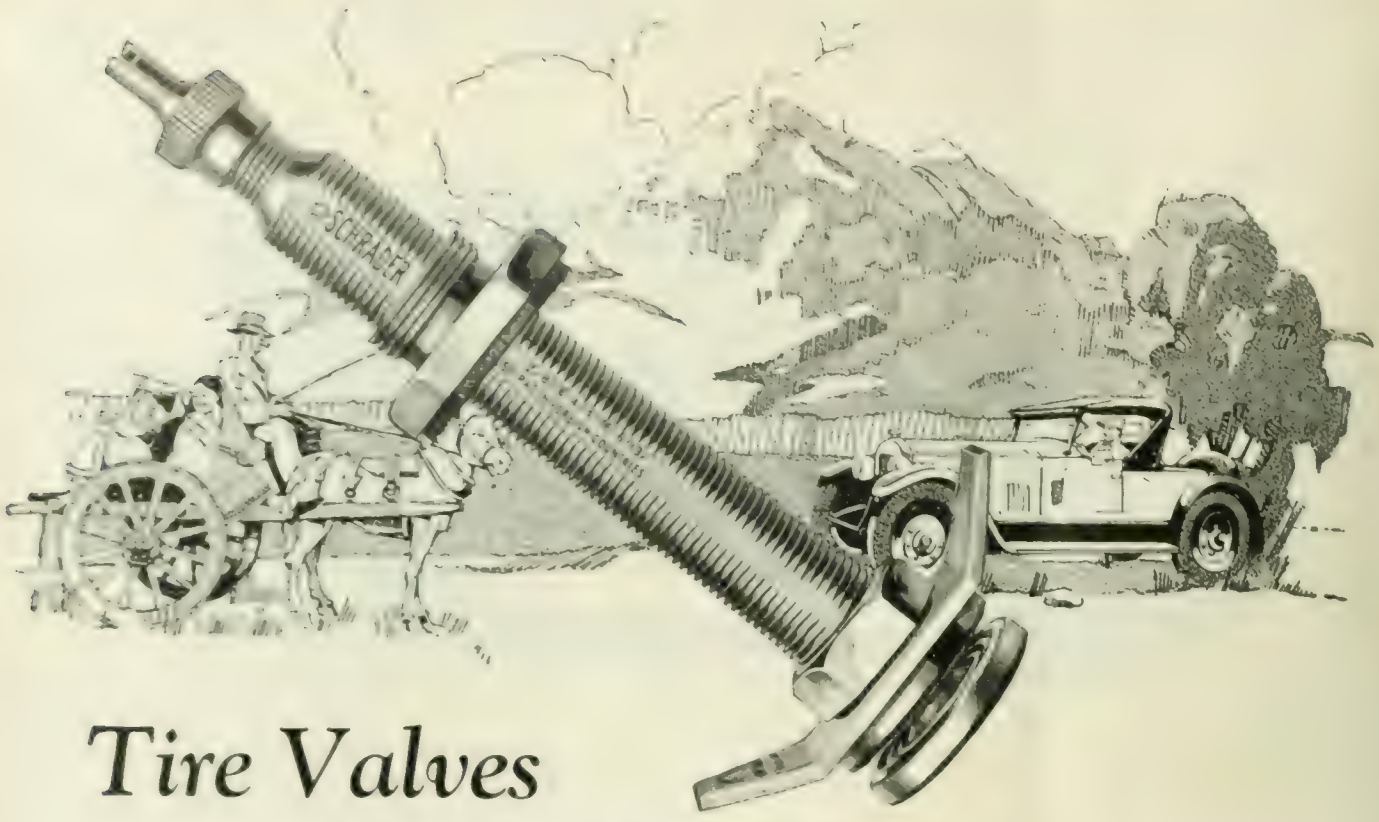


LOCOMOBILE

built to the highest standards of excellence, demands ultimate quality in every part. That is why it is equipped with

WESTINGHOUSE BATTERIES

WESTINGHOUSE UNION BATTERY CO.
Swissvale, Pa.



Tire Valves aid Ireland's progress

IN the land of linens and rugged coasts, Ireland's quaint jaunting-car no longer keeps the center of the road. For the whirr of many motors can be heard across the bogs, crags and dells; and Ireland rides—like the rest of the world—on air held in pneumatic tires.

From the time the first pneumatic tires were made, their life and service have largely depended upon the ability of their tire valves to retain air. A tire can give full mileage only when its valve effectively holds air.

Schrader Valves are air-tight

Wherever civilized man uses motor cars, Schrader Universal Tire Valves are on duty. They successfully retained air in the first pneumatic tire made in the United States. Since then these valves have become standard equipment for pneumatic tires.

Every part of a Schrader Valve is perfectly constructed by skilled workmen. Careful assemblage and rigid inspection further guarantee Schrader Valves to ceaselessly hold in air and enable tires to give their maximum mileage.

Large stocks always ready

Tire manufacturers and supply houses can get immediate shipment of Schrader Products from our large stocks. These products include Schrader Valve Insides, Valve Caps, Bridge Washers, Hexagon Nuts, Rim Nuts, Dust Caps and Bushings.

A. SCHRADER'S SON, Inc., Brooklyn, N. Y.
Chicago Toronto London

Schrader

Makers of Pneumatic Valves Since 1844

Tire Valves · Tire Gauges

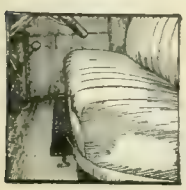
This year it required twice as many Perfection Heaters to meet the public demand for driving comfort as were used last year.
This proves that car buyers are sold on Perfection Heaters—it proves that year after year Perfection Heaters are demonstrating the dependable performance which has made this equipment the acknowledged leader in its field.

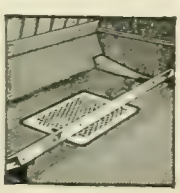
The Perfection Heater & Manufacturing Co.
6545 Carnegie Avenue **Cleveland, Ohio**

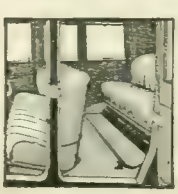
Manufactured in Canada by
Richards-Wilcox Canadian Co., Ltd.
London, Ont.

"The heat is there—why not use it?"

PERFECTION MOTOR CAR HEATERS







These manufacturers provide real winter driving comfort by equipping their closed models with Perfection Heaters without extra charge.

Auburn	Flint-6	McFarlan	Standard "S"
Buick 4-Cyl.	Fox	Moon	Stephens
Buick 6-Cyl.	Gardner	Nash 4-Cyl.	Sterling-Knight
Case	Henney 6	Nash 6-Cyl.	Stevens-Duryea
Cunningham	Hupmobile	National	Studebaker
Dorris	King	Oakland	Velie
Duesenberg	Kissel	Paige	Winton
Durant-4	Kline	Pilot	
Earl	Mercer	Premier	
Elcar	Meteor	R&V Knight	

Taxi Cab Equipment

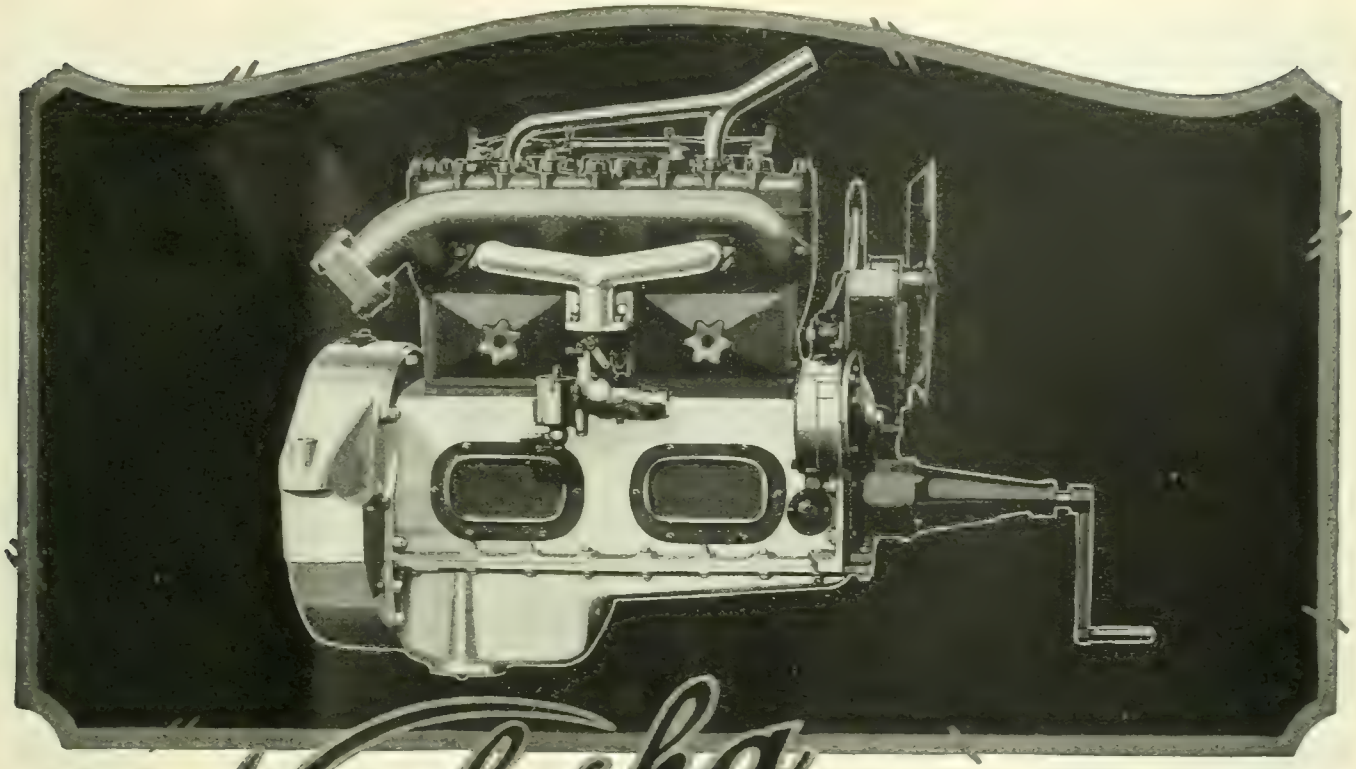
Anchor Top & Body Co.
Barley Motor Car Co.
Elkhart Motor Co.
Premier Motor Corp.
Rauch & Lang, Inc.
Yellow Cab Mfg. Co.

The real works of an automobile heater are hidden under the floor. You can't SEE the quality. Your Safeguard is the Perfection name-plate which you will find on every Perfection Heater.

S. A. E. Publications Price Schedule

	MEMBERS		NON-MEMBERS
	First Copy	Additional Copy	Per Copy
Transactions—Per Part	$2.00	$2.00	$10.00
Journals— 1 Year Subscription	Included in Annual Dues	5.00	10.00 Foreign $12.00
Journals—Single Copies	"	0.50	1.00
Standards Handbook	"	5.00	10.00
Single Sheets for Handbook	"	0.05	0.10
Leather Ring-Binder for Handbook	$4.00	4.00	5.00
Iron and Steel Specifications[1] As Revised July, 1923	In Handbook	2.50	5.00
Engine Testing Forms (per sheet)[1]	"	0.02	0.05
Reprints and Preprints[1] of Papers	Distributed at Meetings	0.25	0.50
Membership Roster	Included in Annual Dues Sent Upon Request	0.50	5.00

[1] Special prices on quantity lots will be submitted on application.



Waukesha
TRADE MARK

BUS and TRUCK MOTORS

Most everyone in the industry, we sincerely believe, has long been familiar with the magnitude and scope of the Waukesha Motor Company's experimental resources.

Its contributions have been recognized and accepted as engineering developments that were sound, practical and mature, for they have made the name a tradition for heavy duty motor supremacy.

Its latest presentation—the Waukesha Bus and Truck Motor—has added not a little to the significant position of its builders, for only an organization so adequately qualified could have developed a transport motor so extraordinarily fine, so outstandingly efficient.

Its great durability is a proven thing. Its economies unparalleled.

THE WAUKESHA MOTOR COMPANY
WAUKESHA, WISCONSIN

The World's Foremost Builders of Bus, Truck, Tractor and Industrial Motors Exclusively

Sales Offices:

1824-1825 Aeolian Building,
33 West 42nd St., New York
Telephone: Longacre 5784

503-505 Capitol Theatre Bldg.,
Madison Ave. Side, Detroit
Telephone: Cadillac 4482

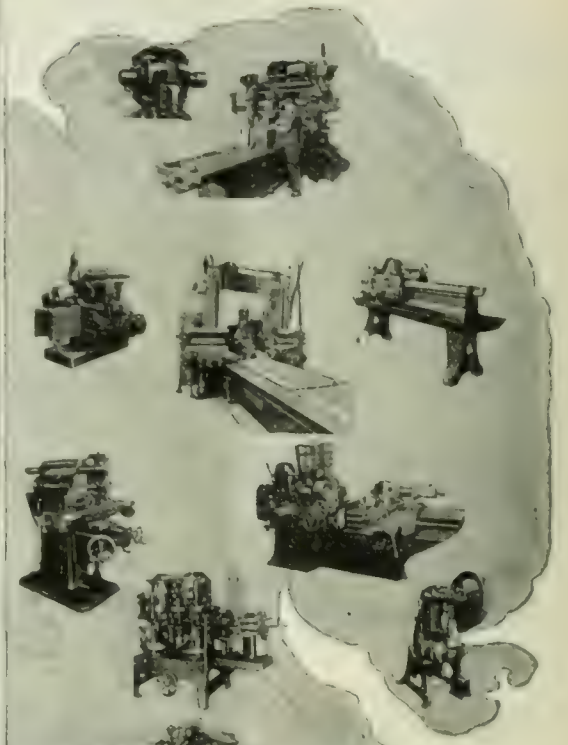
To the Builders of America's Machinery

In millions of machines of all kinds, Bunting Bushing Bearings are worthily representing the specialized service rendered by "Bushing and Bearings Headquarters" to the machinery builders of America.

Bunting's 268 different sizes of "Ready Made" Bushing Bearings fit happily into any production schedule. Over three million always in stock. Few or many, they cost less.

Write for Stock List L showing sizes and prices.

If your needs demand specially made sizes or alloys, send in your blueprints or samples and let this old, experienced organization figure with you.



THE BUNTING BRASS & BRONZE COMPANY - - Toledo, Ohio

Brooklyn and Westchester, N. Y.

Cleveland
Main 5211

Boston
34 Oliver St
Main 8488

BUNTING BUSHING BEARINGS

PATENTED

A Forest of Christmas Trees in Northern Michigan. See America First Through Ainsworth Windshields.

Ainsworth
WINDSHIELD AND VISOR

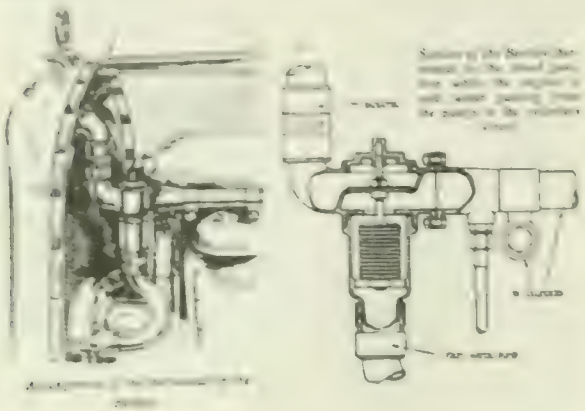
CHRISTMAS

The Christmas season affords both individuals and institutions an opportunity to pause long enough to reflect upon the many blessings enjoyed by mankind, not the least of which is the automobile.

The Ainsworth Manufacturing Company, happy in the knowledge that its products contribute to the comfort of motorists, extends the season's greetings to car owners and members of the automotive industry.

The Ainsworth
WINDSHIELD AND VISOR

AINSWORTH MANUFACTURING COMPANY
DETROIT, MICHIGAN



Standard Equipment on the British "Bentley," too

The [illegible] shows a Sylphon Automobile Temperature Regulator installed on the famous British "Bentley." This car carries it as standard equipment.

Controlling the temperature of the cooling medium, it greatly reduces the wear of valves, pistons and cylinders. Reduces crank case dilution and carbon deposits to a minimum and saves from 15 to 20% in gasoline consumption.

Sylphon TRADE MARK

Automobile Temperature Regulator

Simple and compact, it has but three main parts: the Sylphon Bellows—[illegible] seamless, flexible all-metal expansion member which is the heart of all Sylphon products, a valve and a housing for the Sylphon.

The Sylphon is filled with a highly volatile liquid, which vaporizes at a predetermined temperature, expanding the Sylphon and opening the valve to admit water and contracting and closing the valve when the temperature falls.

Its self-regulating, adapted to pump or thermo-syphon cooling systems, can be installed between the radiator and the engine, either in inlet or outlet water connection. Has no moving parts to wear out, needs no oiling and will outlast the motor.

Standard Equipment on these leading Cars

Cadillac	Lafayette
Columbia	Premier
Kissel-Kar	Rolls-Royce
Lanchester	Straker-Squires
Leyland	Vulcan Trucks

AND MANY OTHER CARS AND TRUCKS

[illegible] are the original [illegible] Sylphon Regulators [illegible]

THE FULTON COMPANY
KNOXVILLE, TENNESSEE
New York Chicago Detroit Philadelphia
Representatives in all Principal Cities

OWEN Dyneto CORPORATION

Owen-Dyneto Corporation
Syracuse, N. Y.

Manufacturers of High Quality

Starting and Lighting Equipment for the Automotive Industry

Simplicity of Design
All Parts Accessible
Exceptionally Efficient

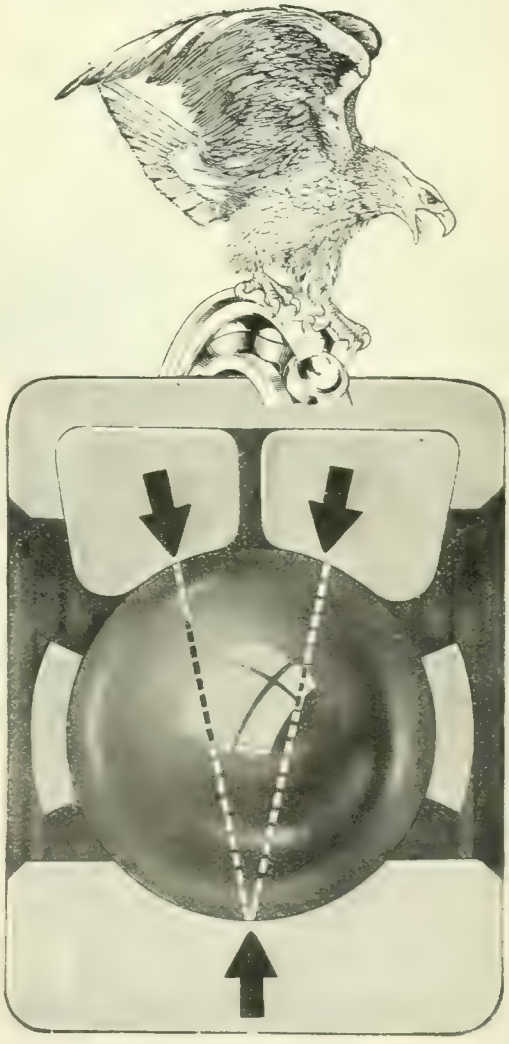
Service Stations in All Principal Cities and Towns

3 Points to carry the Load

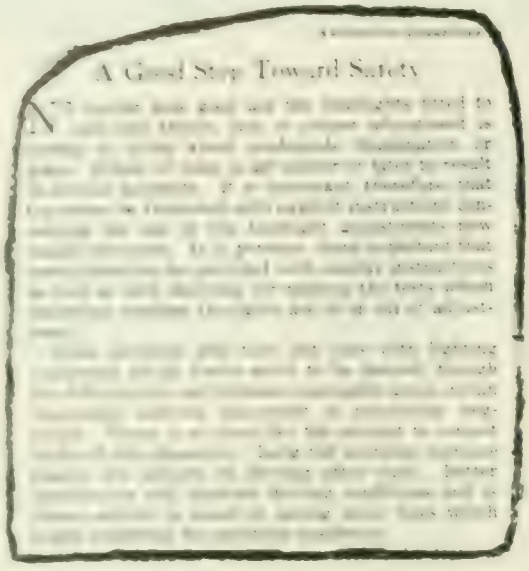
three contact areas instead of the customary two, will withstand all loads and resist all stresses

This increased supporting area of Schatz "Universal" Annular Ball Bearing not only decreases wear and friction, but eliminates danger from shock loads, because direct blows *cannot* be delivered to the balls. Thrust loads are efficiently handled, and violent stresses quietly absorbed. Three points of contact give to this bearing *adaptability* to varying conditions, thrusts and loads.

THE FEDERAL BEARINGS CO., Inc.
Poughkeepsie, N. Y.



Schatz
"UNIVERSAL"
Registered U.S.Pat Off
Annular
BALL BEARING
ADAPTABILITY



HEADLIGHTS, like timing,

must be faultlessly adjusted to function properly.

The subject of headlighting and road illumination is of such importance to the industry as to deserve an engineer's undivided attention.

The results of our experience and the benefits of our knowledge are placed at the disposal of automotive engineers.

Feel free to call upon us. Have no hesitancy in consulting our engineers or placing your headlighting problems before them.

In your catalogs and instruction sheets the subject of headlighting should be covered completely and treated thoroughly. It is too vital to be slighted.

Pass the word along to your advertising director that authoritative information as will enable him to formulate a set of simple, sensible rules and regulations is to be had here—will be given gladly upon request.

THE AMERICAN FLATLITE COMPANY

CINCINNATI. OHIO

DAHLSTROM

Metal Mouldings & Shapes

DURABLE—ARTISTIC

Metal Instrument Panels

Dahlstrom metal instrument panels will not twist or warp. They are easily applied, and instrument openings are neat and carefully made.

Dahlstrom instrument panels are finished by our baked-on process in any color or graining desired.

DAHLSTROM METALLIC DOOR COMPANY

87 Buffalo Street, Jamestown, New York.

PHILADELPHIA DETROIT CHICAGO

Local representatives in principal cities.

NORTH EAST

North East Model LL 225 Watt Generator

The new North East Model LL Generator has a diameter of 5 1/4" and a capacity of 225 Watts. With the addition of this model, North East Generators are now available for every service requirement from 125 Watts to 600 Watts.

NORTH EAST ELECTRIC CO.
ROCHESTER N.Y. U.S.A.

Manufacturers of
Starter-Generators Starting Motors
Generators Ignition-Generators
Ignition Sets Electric Horns
Speedometers

Come to

TEXACO

for efficient plant and shop lubrication

Texaco Machine Oils
Texaco Cutting Oils
Texaco Engine and Turbine Oils

All Texaco Lubricants display the same high quality exemplified by

TEXACO MOTOR OILS

THE TEXAS COMPANY
Texaco Petroleum Products

Dept. AE, 17 Battery Place, New York City

Offices in Principal Cities

Deppé Motors Corporation Superheated Gas System
(Patented)

This system in cars of the 3000 lb. class with engine displacement of 250 cubic inches gives results as follows:

With 100 lb. Compression

Fixed Superheated Gas Mixture

Fixed Adjustments in All Parts with Controlled Combustion

Develop maximum speed of 60 M.P.H.
Twenty-two miles per gallon with existing or any future motor fuels.
Sixteen hundred miles per gallon of lubricant.
Ten to 30 M.P.H. in 9 seconds.
Radiator water normally around 130° F.

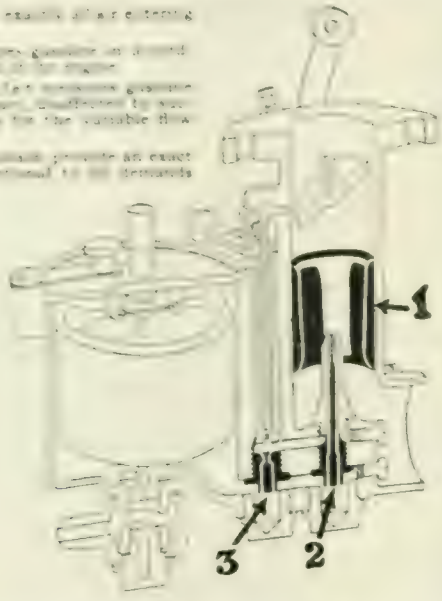
NO THERMOSTATS

Easy starting, no loading.
Practically eliminates carbonization.
No preignition, no autoignition.
No so-called detonations.
Eliminates vibration due to fuel conditions.
Practically eliminates lubricating oil dilution.
No overheating of metals.
Practically eliminates valve grinding.
Practically eliminates bearing adjustments.
Practically eliminates spark-plug troubles.

PRACTICALLY ELIMINATES GEAR SHIFTING.

Deppé Motors Corporation
151 Church Street
New York City

ZENITH CARBURETOR



Dependable!

The Zenith construction, with fixed control of all factors affecting the mixture, allows you to determine exactly the correct setting for your motor, and know it will be maintained.

The Zenith method of manufacture and inspection assures you that every carburetor furnished in production is an exact duplicate in construction and in performance of the one approved by you.

Thus Zenith means uniformity not only in your output, but also in results attained in the hands of users.

ZENITH-DETROIT CORPORATION

Manufacturer of

ZENITH CARBURETORS

DETROIT MICHIGAN

Branches:

NEW YORK · CLEVELAND · CHICAGO

Service Stations in over 800 cities

VENUS PENCILS

The largest selling Quality pencil in the world

VENUS ERASERS are Perfect Made in 12 sizes.

WHEREVER Pencils are used for accurate, responsible work as by engineers and draftsmen) the incomparable VENUS is the first choice.

17 Black Degrees also 3 Copying

Plain Ends, per doz. $1.00
Rubber Ends, per doz. 1.20

At all stationers, drafting supply dealers and stores throughout the world

AMERICAN LEAD PENCIL CO.
227 Fifth Avenue, New York
Dept. EN
and London, Eng.

MAIL COUPON FOR FREE SAMPLE

Send Samples VENUS degrees checked—and a VENUS ERASER.

For bold, heavy lines	6B-5B-4B-3B
For general writing and sketching	2B-B-HB-F-H
For clean, fine lines	2H-3H-4H-5H-6H
For delicate, thin lines	7H-8H-9H

Name

Address

Profession

Johns-Manville Aids Buyers of Automotive Equipment

Automotive Engineers, in the market for automotive equipment, will find Johns-Manville Engineers ready to offer co-operative service on Johns-Manville automotive equipment, at any of our branches. Johns-Manville serves all industry, the automotive being one of many in which we have specialized.

Write, wire or phone our nearest branch.

JOHNS-MANVILLE
Automotive Equipment

Non-Burn Asbestos Brake Band Lining
Johns-Manville Asbestos Brake Lining for Ford Cars
Johns-Manville Asbestos Clutch Rings and Facings
Johns-Manville Speedometers
Johns-Manville Hub Odometer
Johns-Manville Auto Tape
Johns-Manville Automotive Packings

JOHNS-MANVILLE, Inc.

New York City Branches in 56 Large Cities

FRANKLIN DIE-CASTINGS

Two Useful Booklets FREE

Send for Them

The student, the designer and the manufacturer will all find these Franklin publications of decided value.

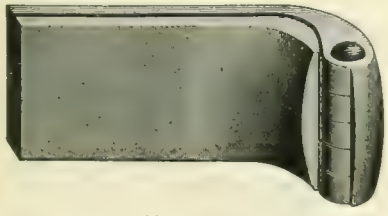
The booklet shown on the left illustrates some of the uses to which die-castings have already been put, and the part they have played in the production of modern inventions. It also contains a condensed table of information regarding the limits, materials, etc., of die-casting work.

The second booklet, specimen pages from which are reproduced on the right, deals with the methods of die-casting manufacture, describing the machines used, the dies in which the parts are cast, and the metals commonly employed. It is written by A. G. Carman, chief metallurgist of the Franklin organization, and is profusely illustrated.

Both booklets are well printed on good paper, and will make a worth-while addition to your information file. Both will be sent on request —free. Write us today.

FRANKLIN DIE-CASTING CORPORATION
Gifford and Magnolia Streets, Syracuse, N. Y.

VEHICLE HARDWARE

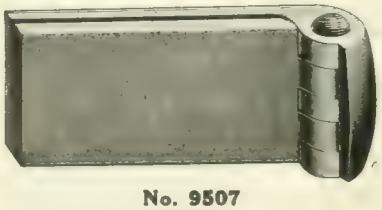


No. 9503

Lamp Brackets

Hinges

Hood Fasteners

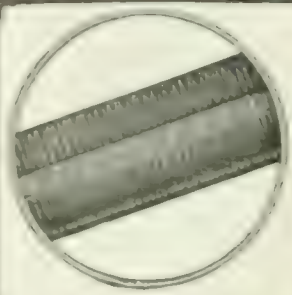


No. 9507

MALLEABLE IRON CASTINGS

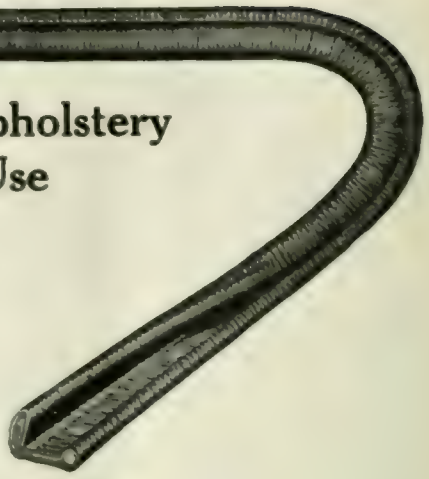
THE EBERHARD MANUFACTURING CO.

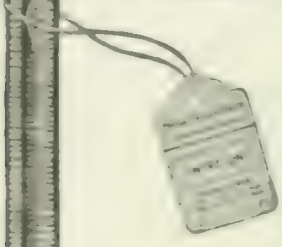
CLEVELAND, OHIO



To Insure Your Car Upholstery Against Wear, Use

"Wire on" Moulding





A combination of Beauty, Refinement and Stability.

WIRE ON is being successfully used in the trimming of tops and open and closed bodies, both pleasure car and bus.

WIRE ON is made with coverings of genuine leather, artificial leather, and cloth. It is easily and successfully applied on any job.

We have been making Mouldings, Gimps, Welts, Robe Rails, Straps and other Automobile Trimmings for many years.

Samples sent upon request.

The George R. Carter Company
Connersville, Indiana

NATIONAL
RADIATORS

Here is probably America's most famous radiator—the National. Both the Zig-Zag Circular and Spiral Tube Nationals are found on some of the best known passenger cars, trucks and tractors. This is significant and should be very indicative to you. Quality cars require quality units. When it comes to the radiator—select the National.

NATIONAL CAN CORPORATION

Radiator Division **Detroit, Michigan**

VIGILANT

Sensitive to any change in the flow of current, Nagel ammeters indicate trouble the moment it starts. Almost as promptly the driver observes the warning—in good time to save his generator or battery. To justify its use, an ammeter must be dependable. That is why Nagel spent years in perfecting this specialized instrument.

NAGEL
AMMETER

THE W.G. NAGEL ELECTRIC CO.
TOLEDO OHIO

The Highest Development of Vulcanized Cotton Fibre

It has taken nearly a half a century to produce Vul-Cot Fibre—a half century of study and experiment to produce a material of exceeding toughness and hardness and that is not brittle.

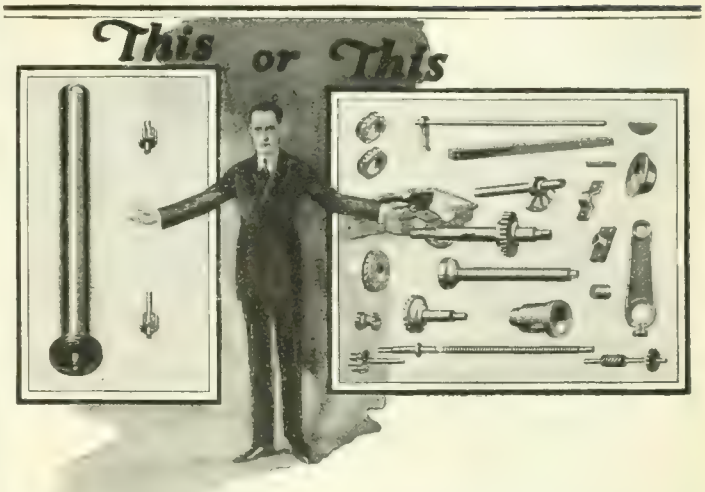
Vul-Cot is made by the oldest and largest manufacturer of Vulcanized Fibre in the country. Every detail, every process in the manufacturing of Vul-Cot Fibre is performed in the three huge plants of the National Vulcanized Fibre Company.

The result is a Fibre that is three times as tough as leather. No ordinary force can crush, break, crack or split it. Its tensile strength is from 9,000 to 14,000 pounds per square inch, with a resistance to shearing up to 13,000 pounds per square inch, and an electrical rupture up to 400 volts per Mil.

We have made Vul-Cot Fibre with such care, with such minute attention to every detail, that we can guarantee it to be free from impurities.

If there is a place for fibre in the composition of your product—if there is a possibility for a material that is as hard as horn, as durable as steel, as adaptable as rubber and yet less costly than any—we will gladly place at your disposal the experience gained through years of making parts for the products of the host of manufacturers who use Vul-Cot Fibre.

National Vulcanized Fibre Co.
Wilmington, Del.



SIMPLICITY is the outstanding feature of Wood-Detroit Hoists—just a piston and two gears, working in oil, comprise the vital *moving* parts of this time-tried dependable mechanism.

Contrast this with the gear trains, worms, splined shafts, jaw clutches, slides, guides, shafting under high torsion, lubricating devices, and similar constructions unavoidable where the necessarily large reduction is made through mechanical instead of hydraulic means.

WOOD DETROIT

Wood-Detroit Hydraulic Hoists have proved their dependability and efficiency in many thousands of installations and for nearly a decade and a half. By specifying Wood-Detroit, you avoid experimenting and uncertainty and assure satisfaction.

And a complete chain of branches and distributors cooperate with you in both sales and service.

Wood Hydraulic Hoist & Body Company
World's Largest Makers of Hydraulic Hoists & Steel Bodies Exclusively
7928 Riopelle Street **Detroit, Mich.**

Testing—Inspection—Balancing 100% Production Basis

Testing, inspection and balancing are accomplished today on a truly 100% production basis by the use of Olsen testing and balancing equipment.

Metal parts of the motor and car should be tested for brinell hardness using an Olsen production type of testing machine.

Springs for valves, clutches and chassis should be subjected to a capacity test on an Olsen production type of spring tester.

Universal joint shafts should be subjected to a proof test using an Olsen production type of Torsion tester.

Crankshafts, flywheels, clutches, and universal joint shafts, etc., should be balanced accurately on a production basis by the Olsen-Carwen Static-Dynamic Balancing Machine.

Connecting rods should be weighed correctly using the Olsen-Lundgren Automatic weighing connecting rod scale.

Send for full information and details and we will recommend the proper equipment to meet your requirements.

SOLE MANUFACTURERS

TINIUS OLSEN TESTING MACHINE COMPANY

500 NORTH TWELFTH STREET
PHILADELPHIA, PA., U. S. A.

Foreign Representatives: Edward S. Herbert, Manchester, England; Andrews & Goodrich Company, Osaka, Japan

Agents Wanted For: Messrs. Edw. S. Herbert, Manchester, England, for the sale of the Herbert Pendulum Hardness Tests

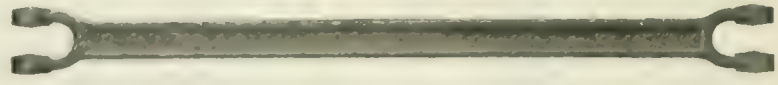
DROP FORGINGS

BACKED BY 40 YEARS' EXPERIENCE

ANYTHING THAT CAN BE DROP FORGED UP TO 300 LBS. ANY ANALYSIS OF STEEL

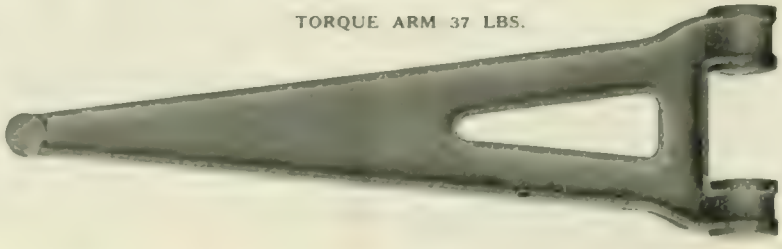
TYPICAL TRUCK FORGINGS

RADIUS ROD 38 LBS.



MODERN METHODS

TORQUE ARM 37 LBS.



ALL FACILITIES

UNION SWITCH & SIGNAL CO.

DROP FORGE DIVISION

Pittsburgh District — Swissvale, Pa.

It is gratifying that Interstate should stand for service and thorough manufacture to so many users of iron and steel bars and wire products. It will please us to establish relations with you on that same basis and live up to it. We believe it will be pleasing to you as well.

Open Hearth Alloy Steel Ingots, Billets, Bars
Wire Rods, Wire, Nails, Rivets and Cut Tacks
Iron Bars and Railroad Tie Plates

INTERSTATE IRON & STEEL CO.
104 South Michigan Avenue
CHICAGO

Interstate Steels

Motor and Transmission Department

Quality may mean "this" to one man and "that" to another—but our idea of what quality really is in motive parts, seems to agree exactly with that of the many foremost manufacturers for whom we have made gears, transmissions and other castings for many years.

Write for the L.M.F. Book

Foundry Department

If you have any castings to be made in Aluminum, Manganese, Phosphor Bronze, Bearing or any Non-Ferrous Metal, we will be glad to quote on your specifications. Probably we can show you a marked saving.

Quality Die Castings

Our daily records of shipments of parts made by our exclusive process of Quality Die Casting is best evidence of our unusual capacity for handling such work. The savings on big orders are big, too.

LIGHT MFG. & FOUNDRY CO.
POTTSTOWN, PA., U. S. A.

SERVICE FLOOD OILING FAN

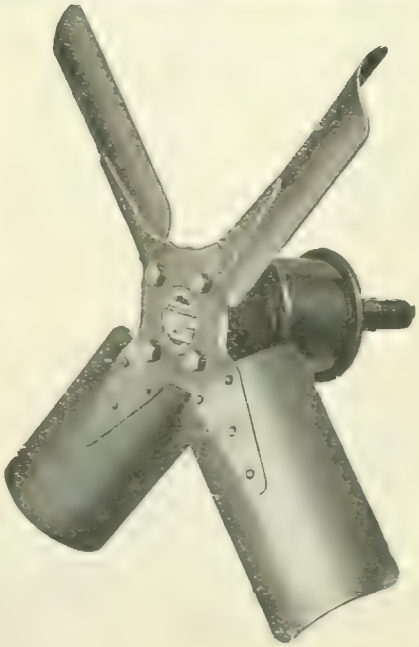
"If It's a Flood Oiling Fan, It's a Service Fan"

THE outstanding feature of the Service Fan is a plain bearing running in a bath of oil. This highly efficient construction eliminates the troubles usually encountered in fan operation. Many thousands of miles elapse before the oil supply needs replenishing.

Four blade and two blade models are made to fit every requirement for passenger cars, trucks and tractors.

Complete information will be sent on request.

Service Products Corporation
201 S. Rural St.
Indianapolis Indiana



Coney Island.

THESE buses are subjected to severe service. Extraordinary seasonable demands are made upon them—continuous running for long hours, congested traffic, sudden stops, quick getaways and heavy loads.

Designers and builders of heavy duty automotive vehicles recognize such conditions and specify the best ignition system obtainable, which accounts for the overwhelming percentage of manufacturers that equip with Eisemann magnetos.

Catalog on request Correspondence invited.

EISEMANN

EISEMANN MAGNETO CORPORATION
William N. Shaw, Pres.
BROOKLYN, N. Y.
DETROIT CHICAGO SAN FRANCISCO

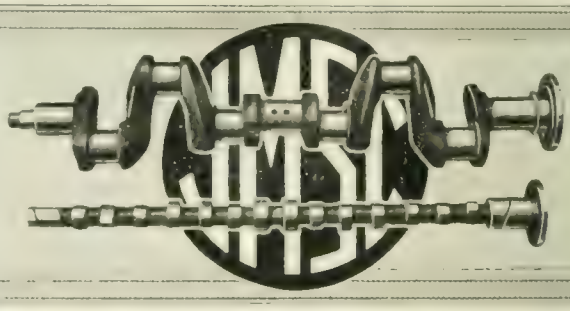
SCOVILL
MANUFACTURING COMPANY
The Oldest Brass Company in America

To write the history of the Scovill Mfg. Co.—its mile long plant, its two hundred buildings, and its diversity of products is to outline the course of industrial growth as it occurred in America the last 121 years.

This great organization, with more than a century of experience in brass craftsmanship is ready to help you in your manufacturing problems, either by supplying the raw materials such as sheet, wire, rod, and seamless tubing, or else by making those small parts or complete articles which you need.

Brass Mill Products
Manufactured Articles to Order

ESTABLISHED 1802
SCOVILL
MANUFACTURING COMPANY



The Largest Manufacturer Finishing Both Crankshafts And Camshafts Exclusively

200,000

motors built annually for passenger cars, tractors and trucks are timed by our camshafts and driven by our crankshafts.

Mr. Motor Builder, our experience and facilities merit your consideration.

JACKSON MOTOR SHAFT COMPANY
JACKSON - - - MICHIGAN

MEMBERS' PROFESSIONAL CARDS

S. A. E., *New York* A. S. M. E., *New York* I. A. E., *London*

CORNELIUS T. MYERS

CONSULTING ENGINEER

REPORTS—DESIGN—TESTS—DEVELOPMENT

Cooperation on Purchase and Upkeep of Trucks, Buses and Rail Cars.

RAHWAY NATIONAL BANK BLDG. RAHWAY, N. J

Chas. M. Manly, A. S. M. E. S. A. E. **Manly and Veal** C. B. Veal, A. S. M. E. S. A. E.

(Consulting Engineers)

mechanical—automotive—industrial

Coordination of engineering and manufacturing requirements in the design, production and operation of automotive power plants and vehicles.

Design, Development, Specifications, Organization, Inspection, Investigation, Tests and Reports

250 West 54th Street, New York City.

S. A. E. A. H. T. A. A. S. M. E. **O. E. Szekely Co.** N. G. E. A. N. A. F. E. M.

MOLINE, ILLINOIS

Mechanical and Automotive Engineers.

Engineering and Laboratory Departments. Complete Experimental Equipment. Testing Machines. Universal Machine Shop and Pattern Shop for Single Piece Reproduction of Our Designs.

FRANCIS W. DAVIS

CONSULTING ENGINEER

DESIGN—DEVELOPMENT—TESTS—OPERATION—MOTOR CARS—TRUCKS—AUXILIARY EQUIPMENT

COMPLETE EXPERIMENTAL DEPARTMENT

124 LEXINGTON STREET WALTHAM, MASS.

E. PLANCHE, A.M., S.A.E., A.S.M.E.

Consulting Engineer, Automotive Designer and Builder

Development Work on Motors, Chassis, Bodies and Accessories.

Special Designs for Economical Operation of Motor Cars.

Special Designs for Economical Building of Automobile Bodies.

GENERAL MOTORS BUILDING, ROOM 5-116, DETROIT, MICH.

A manufacturing interest with large plants in New England and the Middle West and with a surplus of floor space and equipment, would give consideration to the manufacture of mechanisms or devices of metal, preferably of a patentable nature, wherein a large volume of trade can be established, if properly handled.

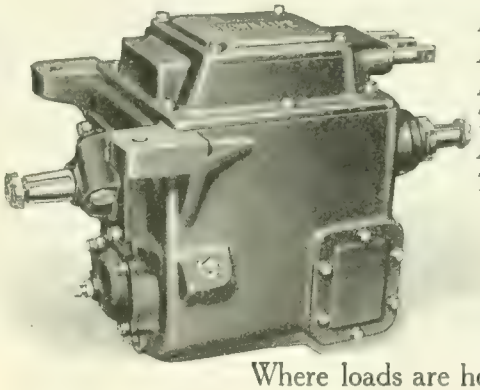
Address replies:

Box 6

Society of Automotive Engineers, Inc.

29 West 39th Street New York

A Giant Among Transmissions



Brown-Lipe Gear Model 60 Four-Speed Top Shift Main Frame Transmission

Where loads are heavy and roads are rough this model transmission proves its great worth.

Only accident or misuse will stop its quiet, efficient operation, and then new, genuine parts are quickly obtainable.

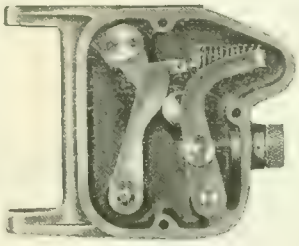
Complete information on this and all other Models given on request.

BROWN-LIPE GEAR CO.

BROWN-LIPE GEAR COMPANY

SYRACUSE, N. Y.

San Francisco Chicago Detroit New York London, Eng.



Sectional View showing simple construction

The Handy Governor

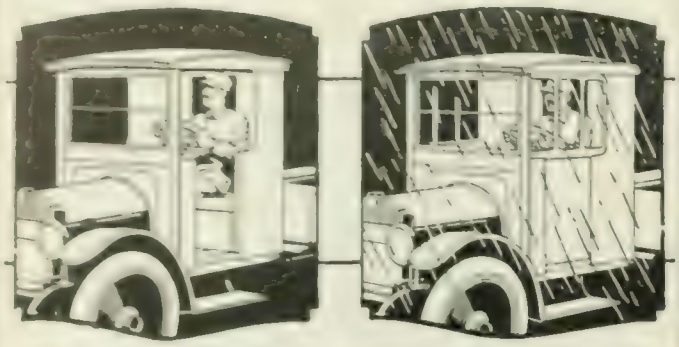
Thousands in use on trucks and tractors giving splendid satisfaction.

Made in standard sizes for motors ranging from 100 to 650 cu. in.

Our engineering department will be glad to discuss your governor problem. Literature on request.

Handy Governor Corporation

3021 Wabash Ave. Detroit, Mich.



THE HIGHLAND CAB

Is a universal unit that can be converted from a wide open cab to one partially or completely closed by the driver without leaving his seat or even stopping his truck.

The Model D cab is now made in three sizes. D-60 is 60" wide. D-54 is 54" wide and D-50 for the speed truck, is 50" wide.

Send for complete bulletin and list of distributors

THE HIGHLAND BODY MFG. CO.
410 Elmwood Place, Cincinnati, O.

U-LOY

Open Hearth and Electric Furnace Alloy Steels are being used in every department of the industry. Perhaps our automotive experts can be of some help on your problems.

UNITED ALLOY STEEL CORP'N - CANTON, O.

G&O Radiators

THE G & O MANUFACTURING CO.
Tubular and Honeycomb Radiators
NEW HAVEN CONN.

Sterling is the largest producer of Dash Ammeters in the world

Sterling Dash Ammeters are made according to S. A. E. standards.

Sterling

Model 500
DASH AMMETERS

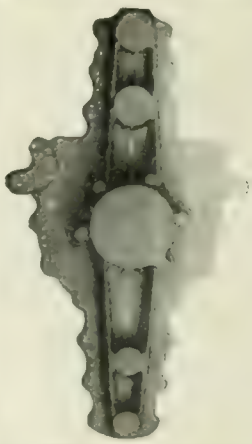
Standard Equipment on many of America's leading cars. Their simple and rugged construction adapts them for long and satisfactory service.

Unique production, long experience, modern daylight plant of fireproof construction, up-to-the-minute special machinery, economical, efficient management, low "overhead" expense, a beautiful thoroughly reliable, time-tested product, these are the advantages which we share with those car manufacturers who make STERLING ammeters standard equipment.

Plain or protecting cases in any style or finish. Etched metal dials furnished in ivory or silver, any scale.

While the foregoing states briefly, samples or quotations

THE STERLING MFG. CO.
2831-53 Prospect Ave., Cleveland, Ohio
Detroit Office, 1309 Kresge Bldg.

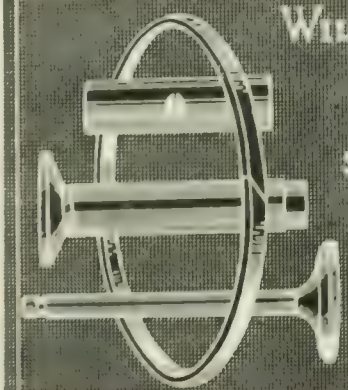


WILLIAMS' SUPERIOR DROP-FORGINGS

Large or small, simple or complicated, any quantity made to order.

DROP-FORGINGS
often cheaper than castings
—always far superior

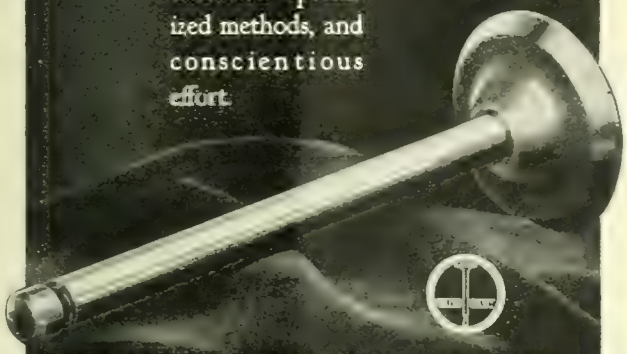
J. H. WILLIAMS & CO.
"The Drop-Forging People"
BROOKLYN BUFFALO CHICAGO



WILCOX MOTOR PARTS & MFG. CO.
SAGINAW - MICHIGAN
VALVES
TAPPETS
PISTON RINGS
PISTON PINS

TOLEDO VALVES

EVERY Toledo Valve is the fine product of long experience, exclusive specialized methods, and conscientious effort.



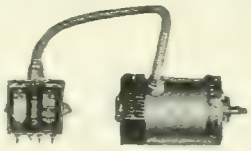
THE TOLEDO STEEL PRODUCTS CO. TOLEDO, OHIO

The BUSINESS POWER *of* LIGHT

LIKE the far-famed illumination of the Great White Way of New York, brightly lighted motor busses advertise your service and attract patrons. There is no longer any question about the power of light to pull business. Night service by busses can be made as profitable as daylight operation.

Leece-Neville equipment was designed to improve and perfect motor bus operation. It is the first lighting and starting equipment in the field with ample capacity to take care of the heavy duty requirements of motor busses. Its reliability, efficiency and economy are recognized by every user. Leece-Neville Generators and Compensators are the *only equipment* which automatically cares for the difference in current required between day and night operation. Send for full details.

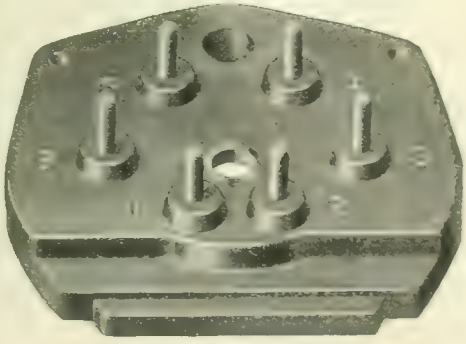
Leece-Neville Electrical Equipment is furnished on the product of
Autocar Company
Brockway Motor Truck Co.
Mack International Motor Truck Corp.
The White Motor Co.
The Haynes Automobile Co.
and a number of others.



THE LEECE-NEVILLE CO
Cleveland, O.

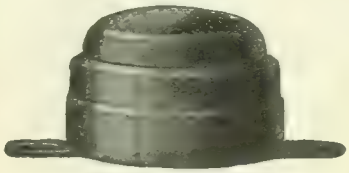
LEECE-NEVILLE

12 Volt Lighting Systems *for* Motor Busses



The new plant of the International Insulating Corporation, now located at Elyria, Ohio, has been completed and is in production on gear shift lever balls, distributor heads, radiator caps, electrical connections, and all moulded parts, either from shellac composition or synthetic material, used on automobiles.

INTERNATIONAL INSULATING CORPORATION
ELYRIA - - OHIO



The Universal Push Button

PERFECT CONTACT IS SECURED ON ANY ANGLE

More Than Two Million in Use

The General Phonograph Mfg. Co.

(Formerly named The Garford Mfg. Co.)
ELYRIA, OHIO

BISHOP-BABCOCK

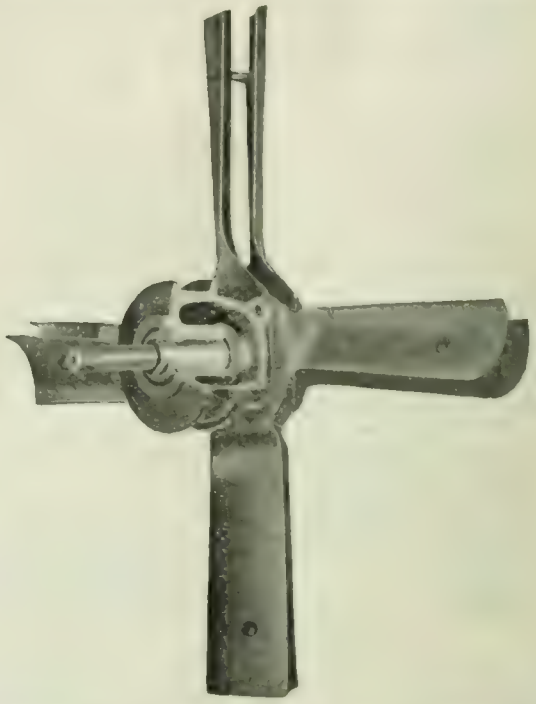
AQUASTAT

The Bishop & Babcock Co.

Automotive Specialties Division

Cleveland, Ohio

MULTIBLADE FAN



DETROIT CARRIER & MFG. CO.

DETROIT, U. S. A.

THE BANTAM BALL BEARING CO.

BANTAM, CONN., U.S.A.

Thrust Bearing Specialists

Bearings Made To Your Requirements

DETROIT OFFICE:
905 Dime Bank Bldg.
Detroit, Mich.

PACIFIC COAST:
Frank M. Cobbledick Co.
1031 Polk St., S. F., Cal.

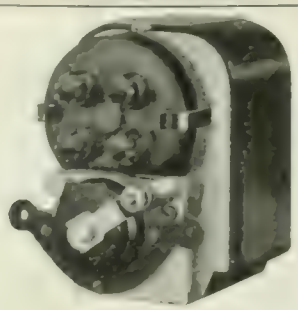
DEPENDABLE

In the operation of a complete and molern Felt Cutting Plant at Detroit, as well as four Felt Mills, the American Felt Company has provided the Automotive Industry with an entirely dependable source of supply. Quality, uniformity and quantity are under complete control from the raw wool to the automobile.

American Felt Company

TRADE MARK

New York · Chicago · Cincinnati · Philadelphia
Boston · Detroit · San Francisco · St. Louis



SIMPLICITY-RUGGEDNESS
EFFICIENCY-RELIABILITY

Always associate these Qualities with

TEAGLE MAGNETO

A BETTER SPARK IN A SIMPLER WAY

Conforms to S. A. E. Standards

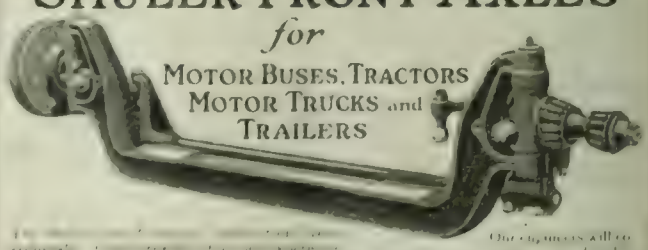
THE TEAGLE CO., Cleveland, O.

You want to know more about this *simplest* magneto—write 1128 Oregon Avenue for details.

SHULER FRONT AXLES

for

MOTOR BUSES, TRACTORS
MOTOR TRUCKS and
TRAILERS



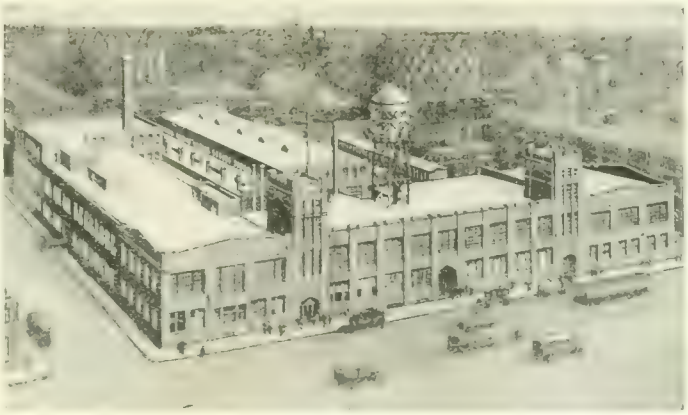
Our engineers will co-operate to develop the most efficient Shuler Front Axle for you.

SHULER AXLE COMPANY, Incorporated

641 JONES STREET LOUISVILLE, KENTUCKY, U. S. A.

GIBSON

Made in this modern plant, where 150,000 square feet of floor space is devoted exclusively to the manufacture of special coil and flat springs. All the latest improvements in methods of manufacture and an equipment for the most scientific heat treatments make it possible to

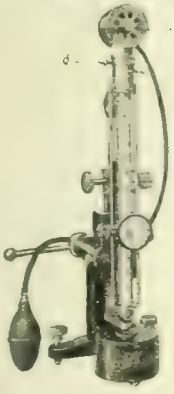


SPRINGS

handle any quantity, size or material. We specialize in high grade springs of carbon or alloy steels for automotive work. Send for our booklet on springs.

The
Wm. D. Gibson Co.
1800 Clybourn Ave.
Chicago Ill.

HARDNESS MEASUREMENTS



Made With **The SCLEROSCOPE**

Are comparatively rapid and inexpensive.
Do not mar finished surfaces.
Do not strain and start fractures in metal.
The only instrument that can be applied to dead soft metals and intensely hard steel.
The only instrument that measures material from extreme thinness to unlimited size.
Cheapest to install, cheapest to maintain.
Recognized as international standard.
Send for free literature.

THE SHORE INSTRUMENT & MFG. CO.
Van Wyck Avenue and Carll Street
Jamaica, New York

MOLTRUP'S

Accurately Finished Free Cutting Cold Drawn

SCREW STEEL

is specified by particular manufacturers of high grade automotive parts.

ROUNDS—HEXAGONS—SQUARES—FLATS
COLD DRAWN SHAFTING AND SPECIAL SHAPES

Other Moltrup Products:
Finished Machine Keys, Standard Woodruff Keys, Finished Machine Rack, Flattened, Ground and Polished Steel Plates and Discs, Foundry Pattern Plates, Finished Crank Shafts

MOLTRUP STEEL PRODUCTS CO., Beaver Falls, Pa.

Tappet Wrench Set No. H70

HERE'S VAN CHROME *the King of* Tappet Wrenches

The Automotive Mechanics favorite set put up in a handy Kit. These Wrenches are drop forged from Chrome Vanadium steel. Long, light, sure-gripping, extra strong, ideal for the whole range of Tappet work.

Herbrand FREMONT U.S.A.

THE HERBRAND COMPANY
Fremont, Ohio

There's a GILLIAM Bearing for practically every application and every location in every make of automotive equipment.

Cups Cones Rollers
Alloy Steel Throughout

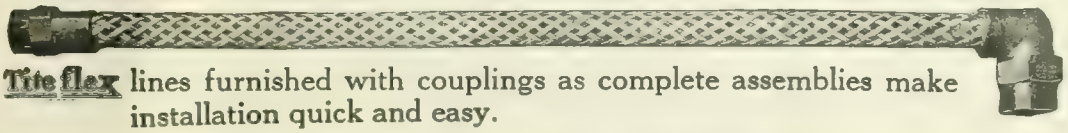
GILLIAM TAPERED ROLLER Bearings

THE GILLIAM MFG. CO. - Canton, Ohio

Titeflex Oil, Water and Gasoline Lines for Automobiles, Trucks and Tractors.

500,000

TITEFLEX LINES INSTALLED IN THIS SERVICE.



Titeflex lines furnished with couplings as complete assemblies make installation quick and easy.

TITEFLEX METAL HOSE CO.

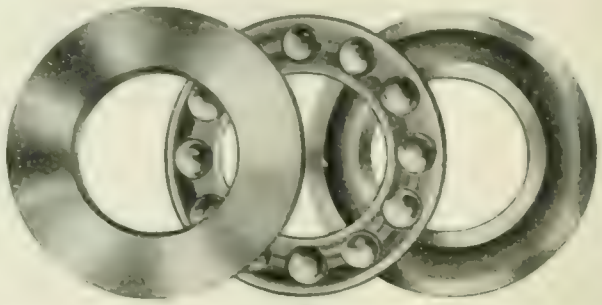
BADGER AVE. and RUNYON ST. **NEWARK, N. J.**

The Bearings Company of America,

manufacturers of STAR Ball Retainers for Thrust, Magneto and Cup and Cone types of Bearings. Complete Thrust Ball Bearings, Angular Contact Thrust Bearings and Angular Contact Radial Bearings (made to your B. P's and requirements).

THE BEARINGS COMPANY OF AMERICA
LANCASTER, PENNA.

Detroit Office, 1012 Ford Bldg.



"PRODUCTS THAT STAND THE TEST"

Manufacturers of—
GASOLINE GAUGES
OIL LEVEL GAUGES
WELDED STEEL RINGS
AND BANDS FOR
FLYWHEEL GEARS
SPROCKETS, ETC.
6" to 60" in Diameter

THE AKRON-SELLE CO.
AKRON, OHIO
35 Years in Business

STANDARD STEEL SPRING COMPANY

CORAOPOLIS, PA.
MANUFACTURERS of LEAF SPRINGS

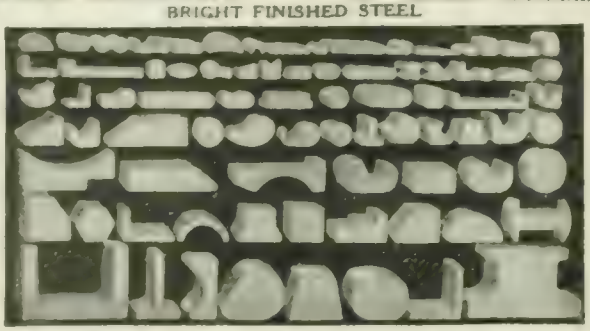
Builders to the most discriminating passenger car and truck manufacturers in the United States and Europe.

UNION DRAWN STEEL COMPANY

ESTABLISHED 1889
Cable Address—"UNIONDRAWN, NEW YORK"

BRIGHT FINISHED STEEL

Manufacturers of
Cold Drawn and Turned and Polished Shafting and Free Cutting Screw Steels
and
Cold Drawn Steel Squares, Flats and Hexagons
Cold Drawn Special Shapes
Cold Drawn or Turned and Polished Pump and Piston Rods
Cold Drawn Elevator Guides
Cold Drawn or Turned and Polished Axles



Cold Drawn or Turned and Polished One Per Cent. and Three and One-Half Per Cent. Nickel Steels and Chromium Steels
Vanadium Steels
Nickel-Chromium Steels
Chrome-Vanadium Steels
Bright Bessemer, Open Hearth, Alloy and Electric Steels
For Special Work in a Wide Range of Analyses

Complete Laboratory and Heat Treating Plant

UNION DRAWN STEEL COMPANY, *General Offices and Works*, Beaver Falls, Pa., and Gary, Ind.

BRANCH OFFICES AND WAREHOUSES *Chicago, Cincinnati, Detroit, New York and Philadelphia*
Pacific Coast Representatives—The Wilson Pump Co., Monadnock Bldg., San Francisco and Washington Bldg., Los Angeles, Calif. and L. C. Smith Bldg., Seattle, Wash.
Foreign Representative—W. E. Enright, 2 and 3 Norfolk St., Strand, London, England, W. C. 2.

Counter Balanced Crank Shafts

MADE BY

THE PARK DROP FORGE CO.
CLEVELAND, OHIO

AUTOMOBILE LAMPS

We are completely equipped to produce motor vehicle lamps, whether of electric, gas or oil construction, in any quantity desired. We solicit the privilege of submitting samples and quoting prices.

The Jno. W. Brown Mfg. Company
Columbus **Ohio**

Belflex Fabric Spring Shackles and Stamped Frame Brackets

Our Engineers are at your disposal.

Write for Information.

The BELFLEX *Corp.*
AUTOMOTIVE PRODUCTS
366 Madison Ave., New York City

Biflex *Spring Bumper*

Blocks other bumpers of all heights. Full-looped ends provide recoil which absorbs terrific crashes. Biflex Brackets can't come loose or rattle.

There's only One Biflex—the Original.

TRADE MARK

The BIFLEX CORPORATION
Waukegan, Ill.

"Protection with Distinction"

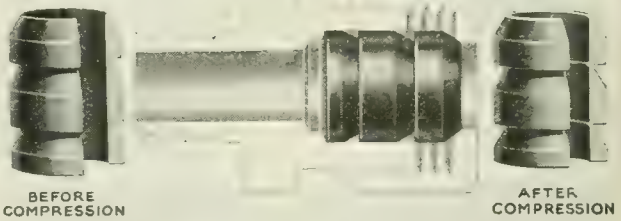
HOOVER

The Worlds Largest Ball Plant

STEEL
BRASS
BRONZE
MONEL METAL
BELL METAL
ALUMINUM
AND HOLLOW BALLS

HOOVER STEEL BALL CO
ANN ARBOR, MICH.

DOHNER
COMPRESSION
COUPLINGS



BEFORE COMPRESSION AFTER COMPRESSION

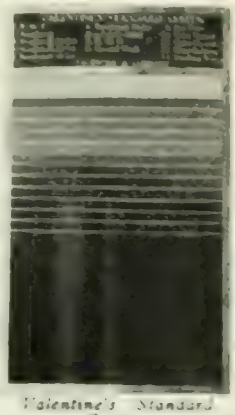
for COPPER, BRASS *or* STEEL
TUBES *for* GAS, GASOLENE
OIL, WATER, STEAM *or* AIR

Approved by Underwriters Laboratories

ASK US FOR DATA SHEETS

The
OHIO METAL PRODUCTS CO.
Dept. "A", Dayton, Ohio.
Sales Office, Free Press Bldg., Detroit, Mich.

VALENTINES



Valentine's Standard System

VALENTINE & COMPANY

FULLER-LEHIGH

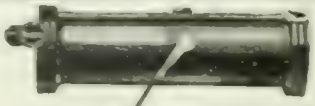
Pulverized Coal Equipment is economically preparing and burning over 40,000 tons of various grades of coal per day for Boilers and Industrial Furnaces.

EQUIPMENT INCLUDES

Pulverized Mills, Air Separator and Screen Type; Crushers; Dryers; Feeders; Burners—Horizontal and Vertical Types; Fuller-Kinyon Conveying Systems.

Let us give you more detailed information.

FULLER-LEHIGH CO.
Fullerton, Pa.



Manufacturers Model

This model especially built for car manufacturers is rapidly being adapted as standard equipment by leading makers. Full information on request.

The Folberth Auto Specialty Co.
Cleveland Ohio

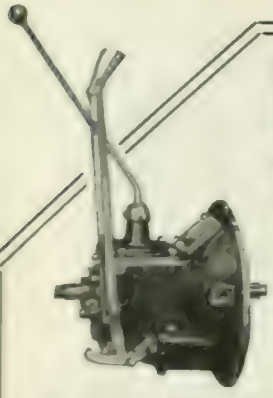
FOLBERTH *Automatic* **WINDSHIELD CLEANER**

The **BENDIX DRIVE** for ELECTRIC STARTERS

AUTOMATIC ENGAGING & DISENGAGING

Standard Equipment on the Electric Starters of a Large Majority of the World's Motor Cars and Trucks.

ECLIPSE MACHINE CO.
ELMIRA - N.Y. -
Walkerville, Ontario



DURSTON TRANSMISSIONS

For passenger cars and trucks up to one-ton capacity. Investigate their adaptability to your requirements.

DURSTON GEAR CORPORATION
134 Maltbie St., Syracuse, N. Y.

Bolts—Nuts Rivets Washers and Forgings for Automotive Construction

The Columbus Bolt Works Co.
COLUMBUS, OHIO

SHEET METAL STAMPING

We are building axle housings, brake drums, and other parts for the heaviest motor trucks ever built, and have ample capacity for still heavier.

With our complete equipment we cover the entire sheet metal stamping line.

We solicit your inquiries.

THE CROSBY COMPANY
BUFFALO, N. Y.

New York Office: 30 Church St.
Cleveland Office: 415 Schofield Bldg.
Detroit Office: 1750 Ford Bldg.
Philadelphia

Cork Gaskets

"True Cut" cork gaskets and washers are absolutely guaranteed against shrinkage and disintegration.

May we submit samples and quote you on your requirements?

Cardboard Cutting & Supply Co.
1571 WELLINGTON AVE. DETROIT

POSITIONS WANTED

BY

153 S. A. E. MEMBERS

Including

EXECUTIVES	PRODUCTION MEN
ENGINEERS	SALESMEN
RESEARCH MEN	SERVICE MEN

Send us notice of position available, for publication, and ask for bulletin of men available

No Charge for the Service

Write to

S.A.E. EMPLOYMENT SERVICE

Society of Automotive Engineers

29 W. 39th Street

New York City

Notice to

S.A.E. MEMBERS

WE KEEP IN TOUCH WITH

1000 FIRST CLASS EMPLOYERS

IN ALL BRANCHES

OF AUTOMOTIVE INDUSTRY

When in search of a position, send us notice of position wanted, for publication, and ask for

Bulletin of Positions Available

INDEX TO ADVERTISERS' PRODUCTS

Marketed as Conforming With S.A.E. Standards and Recommended Practices, and Products for Which There Are No S.A.E. Standards

Absorbers, Shock

Alloys, Aluminum-Vanadium

Alloys, Cupro-Vanadium

Alloys, Ferro-Molybdenum

Alloys, Ferro-Tungsten

Alloys, Ferro-Vanadium

Alloys, Steel (See Steels)

Ammeters, B12

Apparatus, Charging, Electric Vehicle

Apparatus, Ignition**

Apparatus, Laboratory

Appliances, Gas

Axles, Front, Motor-Truck, F1b

Axles, Front, Passenger-Car

Axles, Rear, Motor-Truck

Axles, Rear, Passenger-Car

Axles, Trailer

Babbitt, D10B
- *Franklin Die-Casting Corporation
- *Light Mfg. & Foundry Co.
- *Muzzy-Lyon Co.

Balls, Brass, Bronze, Monel Metal, Aluminum

Balls, Hollow Bronze and Brass

Balls, Steel

Bars, Boring
Williams & Co., J. H.

Bars, Bronze
Bunting Brass & Bronze Co.

Batteries, Storage, B23
- *Electric Storage Battery Co.
- *Willard Storage Battery Co.

Bearings, Babbitt and Aluminum
Bunting Brass & Bronze Co.

Bearings, Babbitt and Bronze
Bunting Brass & Bronze Co.

Bearings, Ball, Angular Contact Type, C32 to C33c
- *Fafnir Bearing Co.
- *New Departure Mfg. Co.
- *S K F Industries, Inc.
- *U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Annular, Extra Small Series, C33
- *Fafnir Bearing Co.
- *New Departure Mfg. Co.
- *S K F Industries, Inc.
- *U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Annular, Extra Large, Light and Medium Series, C27 and C29
- *Fafnir Bearing Co.
- *Hoyt Metal Co.
- *S K F Industries, Inc.
- *U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Annular, Light, Medium and Heavy Series, C26, C28 and C30
- *Fafnir Bearing Co.
- *General Bearing Co., Inc.
- *Hoyt Metal Co.
- *New Departure Mfg. Co.
- *Norma Co. of America
- *S K F Industries, Inc.
- *Standard Steel & Bearings, Inc.
- *U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Annular, Separable (Open) Type, C32
- *Fafnir Bearing Co.
- *New Departure Mfg. Co.
- *Norma Co. of America
- *S K F Industries, Inc.

Bearings, Ball, Annular, Wide Type, C31
- *Brown Lipe Gear Co.
- *Fafnir Bearing Co.
- *New Departure Mfg. Co.
- *S K F Industries, Inc.
- *Standard Steel & Bearings, Inc.
- *U. S. Ball Bearing Mfg. Co.

Bearings, Bronze
Muzzy-Lyon Co.

Bearings, Thrust, Ball, Clutch Release Type, C39
- *Bantam Ball Bearing Co.
- *Bearings Co. of America
- *Fafnir Bearing Co.

Bearings, Ball, Thrust, Single-Direction, Flat-Face Type, C35 and C36
- *Bantam Ball Bearing Co.
- *Bearings Co. of America
- *Fafnir Bearing Co.
- *Norma Co. of America
- *U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Thrust, Single-Direction, Self-Aligning Type, C37 and C38
- *Bantam Ball Bearing Co.
- *Bearings Co. of America
- *Fafnir Bearing Co.
- *Norma Co. of America
- *S K F Industries, Inc.
- *U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Thrust, Steering Knuckle Type, C34
- *Bantam Ball Bearing Co.
- *Bearings Co. of America
- *Fafnir Bearing Co.
- *Norma Co. of America
- *U. S. Ball Bearing Mfg. Co.

Bearings, Roller, Inch-Type
Hyatt Roller Bearing Co.
Timken Roller Bearing Co.

Bearings, Roller, Metric-Type, C13 and C14
- *Bock Bearing Co.
- Hyatt Roller Bearing Co.
- Gurney Mfg. Co.
- *Fafnir Bearing Co.
- *Norma Co. of America
- *S K F Industries, Inc.
- *Shafer Bearing Corporation

Bindings
Carter Co., George R.

Blanks, Gear
Akron Belt Co.
Canton Drop Forging & Mfg. Co.
Central Steel Co.
Link-Belt Co.
Park Drop Forge Co.
Union Switch & Signal Co.

Blanks, Sprocket
Akron Belt Co.

Boards, Floor and Toe
Parish Mfg. Corporation

Bodies, Passenger Car
Baker R & L Co.

Bolts, Carriage
Columbus Bolt Works Co.

Bolts, Connecting-Rod, A5
- *Ferry Cap & Set Screw Co.
- *National Acme Co.

Bolts, Eye
Williams & Co., J. H.

Bolts, Fender
Columbus Bolt Works Co.

Bolts, Hexagon Head, C2
- *National Acme Co.

Bolts, King
Ferry Cap & Set Screw Co.

Bolts, Spring-Center, H4
- *National Acme Co.

Bolts, Spring Shackle
Bower Products Corporation
Ferry Cap & Set Screw Co.

Bolts, Step
Columbus Bolt Works Co.

Bolts, Tie-Rod
Ferry Cap & Set Screw Co.

Brackets, Fender
Parish Mfg. Corporation
South Corporation, A. O.

Brackets, Running-Board, H23
Crosby Co.

Brake-Drums
Crosby Co.

Brass, Laminated
Laminated Shim Co., Inc.

Breakers, Circuit
Dayton Engineering Laboratories Co.

Buckram, Leather
Carter Co., George R.

Bulbs, Incandescent Lamp, B3
- *Westinghouse Electric & Mfg. Co.

Bumpers, Spring
Thermoid Rubber Co.

Bumpers, Passenger Car, C55, and H24
- *Bijur Corporation
- Eaton Axle & Spring Co.
- *Stewart-Warner Speedometer Corporation

Burners
Fuller-Lehigh Co.

Bushings, Babbitt
Muzzy-Lyon Co.

Bushings, Bronze
Bunting Brass & Bronze Co.
Detlaff Co., A. J.
Mueller Metals Co.
Muzzy-Lyon Co.

Buttons, Electric Push
General Phonograph Mfg. Co.

Cable, Insulated, B33
Kerite Insulated Wire & Cable Co.
*Packard Electric Co.

Cabs, Motor Truck, K42b
- *Highland Body Mfg. Co.

Camshafts
Canton Drop Forging & Mfg. Co.
Jackson Motor Shaft Co.
Park Drop Forge Co.
Wyman-Gordon Co.

Caps, Hub
Crosby Co.

Caps, Radiator and Tank, C58n
- *Stewart-Warner Speedometer Corporation.

Carburetors, Cast Iron, A8
- *Byrne, Kingston & Co.
- *Stewart-Warner Speedometer Corporation.
- *Zenith-Detroit Corporation.

Carburetors, Motorcycle
Zenith-Detroit Corporation.

Carburetors, A8
- *Byrne, Kingston & Co.
- *Stewart-Warner Speedometer Corporation.
- *Zenith-Detroit Corporation.

Castings, Aluminum**
- Doehler Die-Casting Corporation
- *Franklin Die-Casting Corporation
- *Light Mfg. & Foundry Co.
- Scovill Mfg. Co.

Castings, Brass**
- Doehler Die-Casting Co.
- *Franklin Die-Casting Corporation
- *Light Mfg. & Foundry Co.
- *Mue. er Metals Co.
- Scovill Mfg. Co.

Castings, Bronze**
- Doehler Die-Casting Co.
- *Franklin Die-Casting Corporation
- *Light Mfg. & Foundry Co.
- *Mueller Metals Co.
- Scovill Mfg. Co.

Castings, Die**
- *Doehler Die-Casting Co.
- *Franklin Die-Casting Corporation
- *Light Mfg. & Foundry Co.
- *Mueller Metals Co.

Castings, Grey Iron
Link-Belt Co.

Castings, Malleable Iron, D9
- *Eberhard Mfg. Co.
- *Link-Belt Co.

Castings, Steel, D7
- *Link-Belt Co.

Chains, Block
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

Chains, Roller, E3
- *Link-Belt Co.
- *Whitney Mfg. Co.

Chains, Silent, E2
- *Link-Belt Co.
- *Morse Chain Co.
Whitney Mfg. Co.

Channels, Window Glass
Dahlstrom Metallic Door Co.

Checks, Door
Carter Co., George R.

Clamps, Hose, C51
Schrader's Son, Inc., A.

Clamps, Machinists'
Eberhard Mfg. Co.
Williams, J. H., & Co.

Cleaners, Windshield
Folberth Auto Specialty Co.

Clips, Spring, H3
Columbus Bolt Works Co.

Clutches, Engine**
- *Brown Lipe Gear Co.

Clutches, Multiple Disc, A1
- *Detlaff Co., A. J.

Clutches, Power Transmission
Link-Belt Co.

Coils, Electrical Equipment
Acme Wire Co.
Dayton Engineering Laboratories Co.

Condensation Products
Bakelite Corporation
Condensite Co. of America
General Bakelite Co.
Redmanol Chemical Products Co.

Connections, Tire-Pump
Schrader's Son, Inc., A.

Controls**
- *Brown Lipe Gear Co.

Cooling Systems**
- *G. & O. Mfg. Co.
- *Long Mfg. Co.
- *National Can Co.

Couplings, Flexible
Thermoid Rubber Co.

(Continued on page 106)

EXPLANATION OF SYMBOLS

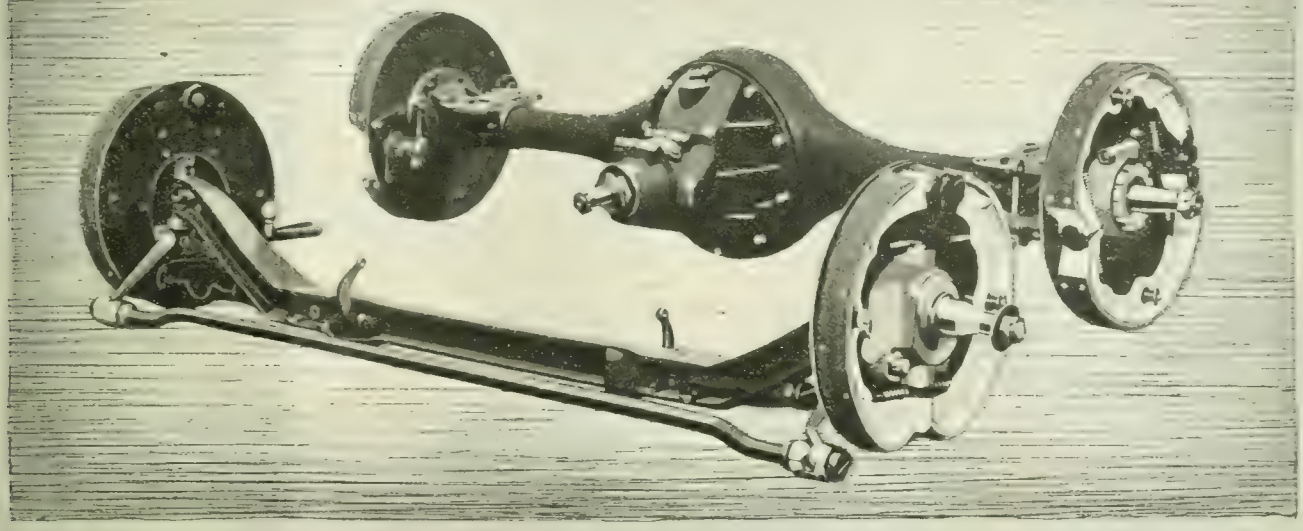
Parts and materials followed by key numbers have been standardized by the S. A. E. The numbers refer to S. A. E. HANDBOOK data sheets on which each standard is published.

*Companies whose names are preceded by an asterisk supply the parts or materials under which the company is listed as conforming with the S. A. E. Standard referred to.

**Parts and materials followed by two asterisks indicate that two or more S. A. E. Standards are applicable. Information as to standards incorporated should be obtained from the manufacturer.

The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 110.

The First American Four Wheel Brake Tested by Use



Experience with Four Wheel Brakes

MANY interesting and significant facts are available for manufacturers who want all possible information on this much discussed subject.

The New **Columbia Axles**

by The Columbia Axle Co · Cleveland

INDEX TO ADVERTISERS' PRODUCTS

Cranes, Portable Electric

Crankshafts

Cups, Oil and Grease, C67

Cutters, Milling

Cutters, Woodruff

Dashes

Dogs, Lathe

Door-Lamps

Drive, Starting-Motor

Drop-Forgings*

Dryers

Durometers

Engines, Motor Truck**

Engine Mountings, Fabric

Engines, Passenger Car**

Engines, Tractor**

Equipment, Pulverized Coal

Facings, Clutch, E19

Fans

Fans, Radiator, A14a

Fasteners, Carpet

Fasteners, Curtain

Fasteners, Hood

Feeders

Fellos - Bands, Motor - Truck, Pneumatic Tire, G4
*Motor Wheel Corporation

Felt, D161

Fenderlights

Fenders

Fibre, Vulcanized

Flanges, Hub

Floors, Metal
Dahlstrom Metallic Door Co

Followers, Cam

Forgings, Brass

Forgings, Drop (See Drop-Forgings)

Forgings, Nickel, Silver and Bronze

Frames, Pressed Steel

Fuses, Electric, B32

Gages, Gasoline

Gages, Oil, B12

Gages, Tire Pressure

Gasoline
Texas Co

Gears, Bevel
Van Dorn & Dutton Co

Gears, Reduction
Van Dorn & Dutton Co.
Waukesha Motor Co

Gears, Spur
Link-Belt Co
Van Dorn & Dutton Co.

Gears, Transmission
Timken Drop Forging & Mfg. Co.
Link-Belt Co.
Van Dorn & Dutton Co
Wyman-Gordon Co

Gears, Worm
Link-Belt Co
Van Dorn & Dutton Co

Generators, Battery Charging (Electric Vehicle)
Westinghouse Electric & Mfg. Co.

Generators (Standard Mountings, B15)
*Atwater Kent Mfg. Co.
*Delco Engineering Laboratories Co
*Electric Auto-Lite Co.
*Leece-Neville Co.
*North East Electric Co
*Remy Electric Corporation
*Westinghouse Electric & Mfg. Co.

Glass, Windshield

Governors
Hall Governor Corporation

Graphite
Dixon Crucible Co., Jos.

Greases, Cup and Gear
Dixon Crucible Co., Jos.
Sun Oil Co
Texas Co.

Handles, Machine-Tool
Williams & Co., J. H.

Head-Lamps, B1

Heaters, Passenger-Car Body
Perfection Heater & Mfg. Co.

Hinges, Door
Eberhard Mfg. Co.

Hinges, Windshield
Eberhard Mfg. Co.

Holders, Tool
Williams & Co., J. H.

Hood Corners
Carter Co., George R

Horns, Hand
Stewart - Warner Speedometer Corporation

Horns, Motor-Driven
Klaxon Co.
North East Electric Co
Stewart - Warner Speedometer Corporation

Hose, Gasoline
Thermoid Rubber Co

Hose, Radiator, C51
*Thermoid Rubber Co.

Housings, Axle
Crosby Co.
Parish Mfg. Corporation
Smith Corporation, A. O.

Hubs, Wheel
Salisbury Axle Co
Smith Corporation, A. O.

Ignition-Generators
North East Electric Co.

Instruments, Heat-Indicating
Stewart - Warner Speedometer Corporation

Instruments, Scientific
Shore Instrument & Mfg. Co.

Insulation, Electric
Bakelite Corporation
Condensite Co. of America
General Bakelite Co
Redmanol Chemical Products Co

Insulation, Molded
Bakelite Corporation
Condensite Co. of America
General Bakelite Co
Redmanol Chemical Products Co

Irons, Body
Columbus Bolt Works Co

Keys, Machine
Moltrup Steel Products Co.

Keys, Spring
Williams & Co., J. H.

Keys, Woodruff
Moltrup Steel Products Co
Whitney Mfg. Co.

Leather
Carter Co., George R

Lining, Brake, C55
*Johns-Manville, Inc.
*Thermoid Rubber Co

Lubricants
(See Oils, Lubricating)

Lubricating Systems
Bassick Mfg. Co.
Bowes Products Corporation

Machines, Balancing
Olsen Testing Machine Co., Tinius

Machines, Power Transmission
Link-Belt Co.

Machines, Testing
Olsen Testing Machine Co., Tinius

Magnetos (Standard Mountings, B14)
*Teagle Co.

Material, Seat

Material, Top and Curtain

Metal, Monel
International Nickel Co.

Mirrors, Rear Vision
Stewart - Warner Speedometer Corporation

Moldings, Cold-Drawn Steel
Dahlstrom Metallic Door Co.

Molybdenum, Metallic
Vanadium Corporation of America

Motors, Electric Vehicle
Westinghouse Electric & Mfg. Co.

Motors (See Engines)

Motors, Starting (See Starting Motors)

Mountings, Torque-Arms, Fabric
Belflex Corporation

Nails
Interstate Iron & Steel Co.

Nickel
International Nickel Co.

Nuts
Columbus Bolt Works Co.

Nuts, Castle, C2
*Ferry Cap & Set Screw Co.
*National Acme Co.

Nuts, Hexagon, C2
*Ferry Cap & Set Screw Co.
*National Acme Co.

Nuts, Slotted, C12 and C14
*Ferry Cap & Set Screw Co.
*National Acme Co.

Nuts, Thumb
Williams & Co., J. H.

Odometers, Hub, F2
*Johns-Manville, Inc.
Stewart - Warner Speedometer corporation

Oils, Lubricating, D151
Dixon Crucible Co., Jos.
Sun Oil Co.
Texas Co.

Packing, Asbestos and Fibrous
Johns-Manville, Inc.

Paints
Dixon Crucible Co., Jos.

Panels, Instrument
Dahlstrom Metallic Door Co.

Parts, Pressed Steel (See Stampings)

Pencils, Drawing
American Lead Pencil Co.
Dixon Crucible Co., Jos.

Pinions, Starting Motor, B18
*Electric Auto-Lite Co.

Pins, Cotter, C7
*Williams & Co., J. H.

Pins, Piston
Wilcox Motor Parts & Mfg. Co.

Pins, Rod-End, C10
*Columbus Bolt Works Co.

Pipe Fittings, Compression Type
Mueller Metals Co
Ohio Metal Products Co

Pipe Fittings, Flared-Tube Type, C46
*Mueller Metals Co.

Piston-Rings, A6
*General Piston Ring Co.
*Piston Ring Co
*Rings Mfg. Co
Wilcox Motor Parts & Mfg. Co

Plates, Flattened, Ground and Polished
Moltrup Steel Products Co.

Pliers
Crescent Tool Co.

Powerplants, Industrial
Waukesha Motor Co

Power Take-Offs, E1
Brown-Lipe Gear Co.

Primers
Valentine & Co.

Products, Screw-Machine
Link-Belt Co
Mueller Metals Co
National Acme Co
Ohio Metal Products Co.
Scovill Mfg. Co
Spicer Mfg. Corporation

Propeller-Shafts
Salisbury Axle Co
Spicer Mfg. Corporation

Pulverizers, Coal
Fuller-Lehigh Co

Push-Rods
Wilcox Motor Parts & Mfg. Co.

Pyroscopes
Shore Instrument & Mfg. Co.

Racks, Machine
Moltrup Steel Products Co.

Radiators**
*G & O Mfg. Co.
*Long Mfg. Co.
*National Can Co.

Rails, Robe
Carter Co., George R.

Rectifiers, Battery Charging
Westinghouse Electric & Mfg. Co.

Reel
Stewart - Warner Speedometer Corporation

Regulators, Temperature
Fulton Co

Regulators, Window
Dura Co.

Relays, Cut-Out
North East Electric Co.

Retainers, Ball
Bearings Co. of America

Ribbons, Fender
Dahlstrom Metallic Door Co.

Rims, Pneumatic Tire, G1 and G2
*Motor Wheel Corporation

Rivets, Brass and Copper
Scovill Mfg. Co.

Rivets, Steel
Columbus Bolt Works Co.
Interstate Iron & Steel Co.

Rod-Ends, C8
*Columbus Bolt Works Co.
*Eberhard Mfg. Co.

Rods, Brass, D114, D115 and D124
*Columbus Bolt Works Co.
*Mueller Metals Co.
*Scovill Mfg. Co.

Rods, Bronze and Copper
Mueller Metals Co.

Rods, Fibre
National Vulcanized Fibre Co.

Roller Bearings (See Bearings, Roller

Running-Boards
Parish Mfg. Corporation
Smith Corporation, A. O.

Scleroscopes
Shore Instrument & Mfg. Co.

Screw Drivers
Crescent Tool Co.

Screws, Cap, C2
*Ferry Cap & Set Screw Co.
*National Acme Co.
*Scovill Mfg. Co.

Screws, Thumb
Williams & Co., J. H.

Searchlights
Stewart-Warner Speedometer Corporation

Shafting
Moltrup Steel Products Co.

Shafts, Rear Axle
Salisbury Axle Co

Shapes (Extruded Brass, Bronze and Copper
Mueller Metals Co.

Sheets, Brass, D111
*Scovill Mfg. Co.

Sheets, Fibre
National Vulcanized Fibre Co.

Shields, Radiator
Hayes Mfg. Co.

Shields, Running-Boards
Hayes Mfg. Co.

Shims, Laminated
Laminated Shim Co., Inc.

Sills, Body
Smith Corporation, A. O.

Speedometers
Stewart-Warner Speedometer Corporation

Spokes, Wood, Motor Truck, F1
*Motor Wheel Corporation

Spokes, Wood, Passenger Car, F1a
*Motor Wheel Corporation

Spring-Shackles, Fabric
Belflex Corporation

Springs, Coiled
Gibson Co., Wm. D.

Springs, Flat
Gibson Co., Wm. D.

Springs, Motor Truck, H9
*Perfection Spring Co.
Sheldon Axle & Spring Co.
*Standard Steel Spring Co.

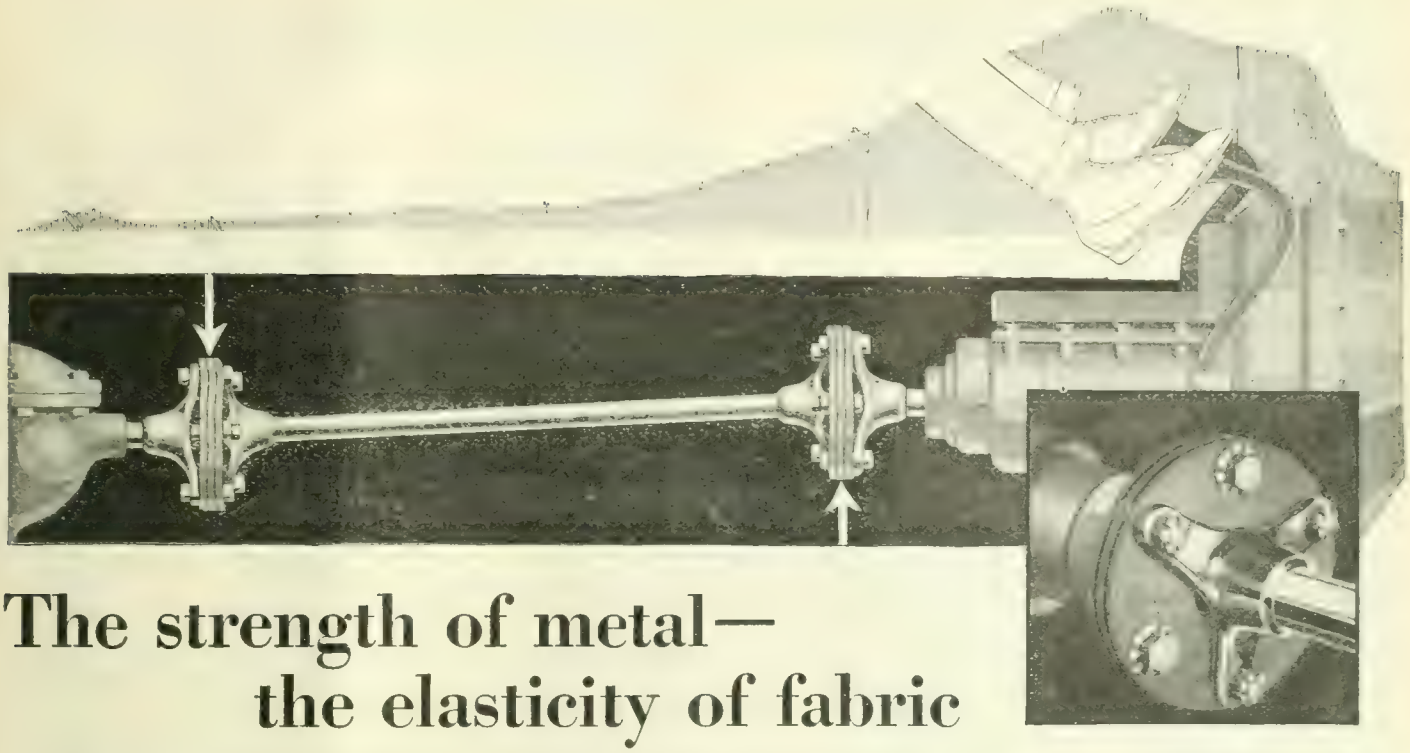
Springs, Passenger-Car, H8
*Perfection Spring Co.
Sheldon Axle & Spring Co.
*Standard Steel Spring Co.

Springs, Tractor
Standard Steel Spring Co.

Sprockets, Roller-Chain, E4
*Link-Belt Co.
*Whitney Mfg. Co.

Sprockets, Silent-Chain
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

(Continued on page 108)



The strength of metal— the elasticity of fabric

Fanwise Construction has made the Thermoid-Hardy fabric disc a practical necessity for motor cars

For years motorists endured the knocks, jars, and lost motion caused by the wear-down of metal universals. Delicate gears and bearings suffered irreparable injury.

Then the fabric disc was invented. Its flexibility cushioned the blows of starting, shifting, and bumping over rough roads. But not until Fanwise Construction was perfected did the fabric universal overcome every previous objection.

Balanced to meet every stress

Take a look at the diagram of the Thermoid-Hardy disc. It is built up fanwise, each layer overlapping and turned. The strands of each layer run in a different direction. Each sector is of uniform strength and elasticity. Every stress is balanced—

—the torsional, between the bolt holes
—the centrifugal, from the center outward
—the lateral, from the forward and back motion of the shaft.

This holds the shaft in true on every revolution. It eliminates vibration and "whipping."

Now notice the diagram of the ordinary fabric universal. Built up so that only *one* driving bolt can pull "with" the strands of cotton—the other two tugging *across* them—your disc soon stretches out of shape. Vibration naturally follows, bringing jars and lost motion.

Only in the Fanwise Construction of the Thermoid-Hardy disc do you get the flexibility of fabric, the rugged strength of metal.

Thermoid-Hardy discs are now packaged for distribution through jobbers and dealers for replacement sales. Full information, prices, and discounts sent on request.

A book you should have

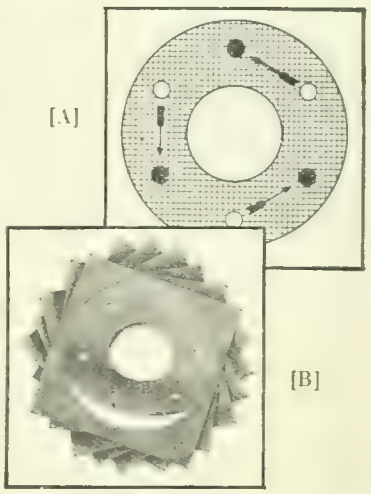
We have prepared a book, "Universal Joints—Their Use and Misuse," that treats the subject from every angle—the mechanical principles, construction, lubrication, manufacture, strength tests, and records of performance. Send for your copy today.

THERMOID RUBBER COMPANY
Sole American Manufacturers
Factory and Main Offices: Trenton, N. J.
New York, Chicago, Los Angeles, Detroit, Atlanta, Seattle, Kansas City, Boston, Cleveland, San Francisco, London, Paris, Turin

THERMOID-HARDY
UNIVERSAL JOINT

Makers of "Thermoid Hydraulic Compressed Brake Lining" and "Thermoid Crolide Compound Tires"

Allis Chalmers Mfg. Co.
The Autocar Co.
Available Truck Co.
Barley Motor Car Co. (Roamer)
Chandler Motor Car Co.
Crow-Elkhart Motor Corp.
Jas. Cunningham Son & Co.
Dart Truck & Tractor Corp.
The Dauch Mfg. Co.
Diamond T Motor Car Co.
Doane Motor Truck Co.
Dort Motor Car Co.
Fageol Motors Co.
H. H. Franklin Mfg. Co.
Garford Motor Truck Co.
Gramm-Bernstein Motor Truck Co.
Hawkeye Truck Co.
Hendrickson Motor Truck Co.
Highway Motors Co.
Holt Mfg. Co.
Indiana Truck Co.
International Harvester Co. of A., Inc.
International Motor Co.
Jackson Motors Corp.
Kelsey Motor Co.
Kentucky Wagon Mfg. Co., Inc.
King Zeitler Co.
Lakewood Eng. Co.
Lexington Motor Co.
Locomobile Co.
Maxwell Motors Corp.
Menominee Motor Truck Co.
Mercer Motors Co.
Moreland Motor Truck Co.
Nelson & LeMoon
E. A. Nelson Automobile Co.
Nelson Motor Truck Co.
D. A. Newcomer Co.
O'Connell Motor Truck Co.
Olde Motor Works.
Oliver Tractor Co.
Oneida Motor Truck Co.
Packard Motor Car Co.
Parker Motor Truck Co.
Patriot Motors Co.
Reliance Motor Truck Co.
Reo Motor Car Co.
Reynolds Motor Truck Co.
Root & Van Dervoort Eng. Co.
Sanford Motor Truck Co.
Southwark Fdy. & Mach. Co.
Stoughton Wagon Co.
Studebaker Corp.
Stutes Mar Tractor Co.
Templar Motors Co.
Tioga Steel & Iron Co.
Towmotor Co.
Traffic Motor Truck Co.
Transport Truck Co.
Twin City Four Wheel Drive Co., Inc.
United Motors Co.
Walter Motor Truck Co.
Ward La France Truck Corp., Inc.
Geo. D. Whitcomb Co.
Wichita Motors Co.
H. E. Wilcox Motor Co.
Willys-Overland, Inc.
Worthington Pump & Machinery Corp.
Zeitler & Lamson Truck & Tractor Co.



[A] *Above is an ordinary fabric disc, its layers of fabric laid parallel. The three black holes are the driving bolts—the three white ones the driven. Note that the left hand driving bolt is the only one that can pull in the direction of the cotton strands. The other two must pull on a bias. This stretches the whole disc out of true, causing vibration and "whipping" of the shaft.*

[B] *Now examine the Thermoid-Hardy patented Fanwise Construction. The disc is built up with the strands of each layer running in a different direction. Each sector is equally strong, equally elastic. Every stress is balanced—the torsional, the centrifugal, and the lateral. This eliminates vibration and holds the shaft in true on every revolution.*

INDEX TO ADVERTISERS' PRODUCTS

Stampings

Starter-Generators

Starting, Automatic Meshing Drive for

Starting-Motors (Standard Mountings, B16)

Steel, Carbon, D4

Steel, Chromium, D6

Steel, Chromium-Vanadium, D6

Steel, Leaf-Spring, D77

Steel, High-Chromium
Atlas Steel Corporation

Steel, Molybdenum
Interstate Iron & Steel Co

Steel, Nickel, D5
*Atlas Steel Corporation
*Central Steel Co.
*Interstate Iron & Steel Co.
*Union Drawn Steel Co.
*United Alloy Steel Corporation

Steel, Nickel-Chromium, D5
*Atlas Steel Corporation
*Central Steel Co.
*Interstate Iron & Steel Co.
*Union Drawn Steel Co.
*United Alloy Steel Corporation

Steel, Silico-Manganese, D6
*Atlas Steel Corporation
*Central Steel Co.
*Interstate Iron & Steel Co.
*United Alloy Steel Corporation

Steel, Screw Stock, D4
Milltown Steel Products Co.
Union Drawn Steel Co.

Steel, Tungsten, D6
*Atlas Steel Corporation
*United Alloy Steel Corporation

Steering Gears (Standard Wheel Hub), J4
*Ross Gear & Tool Co.

Stop Lights
Stewart-Warner Speedometer Corporation

Superheat System, Gasoline
Doyle Motors Corporation

Surfacers
Valentine & Co.

Switches, Combination
Dayton Engineering Laboratories Co.

Switches, Lighting
Westinghouse Electric & Mfg. Co

Switches, Starting
Dayton Engineering Laboratories Co.
Electric Auto-Lite Co.
Lewis-Neville Co.
North East Electric Co.
Westinghouse Electric & Mfg. Co.

Syphon, Automobile
Fulton Co.

Systems, Lubrication (See Lubricating Systems)

Systems, Pulverized-Material Conveying
Fuller-Lehigh Co.

Tachometers (with Standard Drive), C75
*Johns-Manville, Inc.

Tacks
Interstate Iron & Steel Co.

Tank Caps and Flanges
Akron-Selle Co.

Tanks, Gas
Prest-O-Lite Co.

Tanks, Vacuum, C45
*Stewart-Warner Speedometer Corporation

Tape, Insulated
Johns-Manville, Inc.

Tappets
Wilcox Motor Parts & Mfg. Co.

Testers, Hardness
Shore Instrument & Mfg. Co

Thermostats, A14
*Bishop & Babcock Co.
*Fulton Co

Timer-Distributors, B13
*Atwater Mfg. Co.
*Dayton Engineering Laboratories Co
*Electric Auto-Lite Co
*North East Electric Co.

Tire Carriers
Detroit Carrier & Mfg. Co.

Tire Locks
Detroit Carrier & Mfg. Co

Tire-Pumps, Transmission Type, E1
*Detroit Carrier & Mfg. Co.

Tires, Pneumatic, G1
*Kelly-Springfield Tire Co
*Thermoid Rubber Co.

Tires, Solid, G10
*Kelly-Springfield Tire Co.

Tools
Haynes Stellite Co
Williams & Co., J. H.

Tools, Piston Regrooving
Ross Mfg. Co

Tools, Production
Kelly Reamer Co.

Torque-Arms
Smith Corporation, A. O.

Torsion-Rod Assemblies
Steel Products Co.

Tractors, Industrial
Baker R & L Co.

Transmissions**
*Brown-Lipe Gear Co.
*Durston Gear Corporation
*Light Mfg. & Foundry Co.

Trucks, Industrial
Baker R & L Co.

Tubing, Brass, D116
*Mueller Metals Co.
*Scovill Mfg. Co.

Tubing (Tapered), Brass Tubing, Copper, D117
*Mueller Metals Co.
*Scovill Mfg. Co

Tubing, Flexible, C52
*Titeflex Metal Hose Co.

Tubing, Flexible Metal, C52
Titeflex Metal Hose Co.

Tubing, Rubber
Thermoid Rubber Co.

Tubing, Steel, D98
*Smith Corporation, A. O.

Tubing, Windshield
Dahlstrom Metallic Door Co.

Tungsten, Metallic
Vanadium Corporation of America

Universal-Joints, E6
*Spicer Mfg. Corporation
*Thermoid Rubber Co.

Valves, Fuel Reserve
Service Products Corporation

Valves, Poppet, A4
*Bunting Brass & Bronze Co.
Steel Products Co.
*Toledo Steel Products Co.
Wilcox Motor Parts & Mfg. Co

Valves, Tire
Schrader's Son, Inc., A.

Varnishes, Finishing
Valentine & Co.

Varnishes, Rubbing
Valentine & Co.

Ventilators, Cowl
Service Products Corporation

Voltmeters, B12
*Sterling Mfg. Co.
Westinghouse Electric & Mfg. Co.

Washers, Air
Stewart-Warner Speedometer Corporation

Washers, Plain, C5c
Interstate Iron & Steel Co.

Washers
Columbus Bolt Works Co.

Welding, Electric
Steel Products Co.

Welding Rod, Bronze
Mueller Metals Co.

Wheels, Pressed Steel Disc
Motor Wheel Corporation

Wheels, Wood
Motor Wheel Corporation

Wicks, Felt
American Felt Co.

Windshields
Ainsworth Mfg. Co.

Wire (See Cable, Insulated)

Wire, Magnet
Acme Wire Co.

Wire Products
Interstate Iron & Steel Co.

Wrenches
Crescent Tool Co.
Williams & Co., J. H.

The Index to Advertisers is given on page 110

Have We Your Correct Address?

The New York Office is just as anxious as the individual members that they receive THE JOURNAL and other communications promptly.

This result cannot be achieved unless

Members notify the office whenever they make a change in their business connection or their mail address or both.

Members who have been in the service of the Government either as civilians or in the Army or Navy let us know when they leave the service and also when they re-enter commercial fields.

Your cooperation is necessary and will be greatly appreciated.

May We Have It?

SOCIETY OF AUTOMOTIVE ENGINEERS, Inc.

STORAGE BATTERY
Willard
SERVICE STATION

1 T. A. Willard—who has done and is doing more for storage battery improvement than any other one individual.
2 The Willard Organization—for fifteen years leaders in storage battery manufacture and distribution.
3 The Willard Laboratories—physical, chemical, mechanical and electrical—the finest equipment for battery research in the country.
4 The Willard Factory—with the size, resources and volume for quantity production to a high quality standard.
5 Original Equipment on 137 makes of motor cars and trucks; 93% have always used Willard Batteries.
6 The Friendship of 20,000 car dealers.
7 The Good Will of 10,000,000 car owners.
8 The leading Wood-Insulated Battery.
9 The only Threaded Rubber Battery.
10 The most extensive and long-continued and consistent national advertising.
11 The most efficient co-operation with the dealer's local advertising.
12 Membership in the original and most efficient national battery service to car owners.

Back of the Sign

12—Service that Sells

No service is 100% perfect. There will always be some customers who can't be satisfied, some dealers who will not satisfy.

But, by and large, there's no group of men in the industry doing what Willard Service Station Dealers are doing to earn and hold the good will of car dealers and car owners.

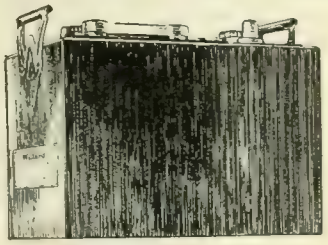
Willard Service is the oldest established battery service, the truly national, the most efficient and by far the best equipped for its job.

From North to South and from sea to sea the Willard sign is known to American motorists as standing for fair and expert service.

It is the best that a live-wire, progressive battery merchant can hang out in front of his place of business.

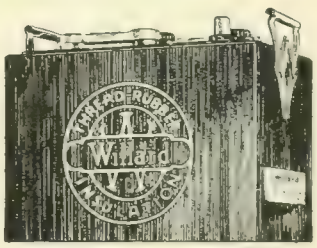
WILLARD STORAGE BATTERY CO., Cleveland, O.
In Canada the
Willard Storage Battery Co. of Canada, Limited, Toronto, Ontario

Willard STORAGE BATTERIES



The acknowledged leader of wood-separator batteries for fifteen years.

Original Equipment on 137 Motor Cars and Trucks



The Threaded Rubber Battery that created a new standard of battery value.

INDEX TO ADVERTISERS

A

B

Bower Roller Bearing Co..... 75
Brown-Lipe Gear Co..... 95
Bunting Brass & Bronze Co..... 82

C

D

Dura Co.....13, 32, 33

E

F

Fuller Bearing Co..... 12

G

G & O Mfg. Co..... 96
General Bakelite Co..... 27
Gibson Co., Wm. D..... 99
Gilliam Mfg. Co..... 99
Gurney Ball Bearing Co..... 14

H

Handy Governor Corporation.... 95
Hayes Mfg. Co..... 68
Haynes Stellite Co..... 67
Herbrand Co..... 99
Highland Body Mfg. Co..... 96
Hoover Steel Ball Co.....101
Hyatt Roller Bearing Co..... 44
Hydraulic Brake Co..... 53

I

International Insulating Corporation 97
International Nickel Co..... 72
Interstate Iron & Steel Co..... 93

J

Jackson Motor Shaft Co..... 94
Johns-Manville, Inc. 88
Johnson Bronze Co..... 25

K

Kelly-Springfield Tire Co..... 10
Kerite Insulated Wire & Cable Co. 1
Klaxon Co..... 71

L

Laminated Shim Co., Inc..... 30
Light Mfg. & Foundry Co..... 93
Long Mfg. Co..... 39

M

Members' Professional Cards.... 95
Moltrup Steel Products Co..... 99
Mueller Metals Co..... 62
Muzzy-Lyon Co..... 40

N

Nagel Electric Co., W. G..... 91
National Acme Co..... 45
National Can Corporation..... 90
National Vulcanized Fibre Co... 91
New Departure Mfg. Co..... 64
Norma Co. of America..... 2
North East Electric Co..... 87
Notes and Reviews..... 10

O

Ohio Metal Products Co.....101
Olsen Testing Machine Co., Tinius 92
Owen-Dyneto Corporation 84
Oxford Varnish Corporation...28, 29

P

Packard Electric Co..... 24
Parish Mfg. Corporation..... 65
Park Drop Forge Co. 101
Perfection Heater & Mfg. Co..... 79
Piston Ring Co..... 60
Prest-O-Lite Co., Inc.....50, 51

R

Redmanol Chemical Products Co.. 27
Reus Mfg. Co..... 76
Ross Gear & Tool Co..... 46

S

S K F Industries, Inc..... 19
Schrader's Son, Inc., A..... 78
Scovill Mfg. Co..... 94
Service Products Corporation.... 93
Shafer Bearing Corporation..... 6
Shore Instrument & Mfg. Co..... 99
Shuler Axle Co., Inc..... 98
Smith Corporation, A. O..... 74
Standard Steel & Bearings, Inc.. 5
Standard Steel Spring Co.....100
Steel Products Co..... 7
Sterling Mfg. Co..... 96
Stewart Mfg. Corporation 31
Stewart-Warner Speedometer Corporation 57
Sun Oil Co.....111

T

Taylor Instrument Companies.... 8
Teagle Co..... 98
Ternstedt Mfg. Co., Inside Back Cover
Texas Co..... 87
Thermoid Rubber Co.....11, 107
Timken-Detroit Axle Co..... 26
Timken Roller Bearing Co..... 52
Titeflex Metal Hose Co..... 99
Toledo Steel Products Co..... 97

U

Union Drawn Steel Co.....100
Union Switch & Signal Co..... 92
United Alloy Steel Corporation.. 96
United States Ordnance Co..... 9
U. S. Ball Bearing Mfg. Co..... 55

V

Valentine & Co.....102
Van Dorn & Dutton Co..... 37
Vanadium Corporation of America 61

W

Watson Co., John Warren, Inside Front Cover
Waukesha Motor Co..... 8
Westinghouse Electric & Mfg. Co. 48
Westinghouse Union Battery Co.. 77
Whitney Mfg. Co..... 15
Wilcox Motor Parts & Mfg. Co... 96
Willard Storage Battery Co.....109
Williams & Co., J. H..... 96
Wood Hydraulic Hoist & Body Co. 91
Wyman-Gordon Co., Opposite first reading page

Z

Zenith-Detroit Corporation 88

An index to advertisers' products is given on pages 104, 106 and 108

SUN OILS

Increasing an important safety factor

You know that in cold weather particularly, the average rate of dilution of lubricant by fuel is very rapid. This fact was emphasized at the summer meeting of the S. A. E., in the report of the Research Division covering tests of fuels made under winter conditions.

To obtain proper lubrication, adequate viscosity is essential. To ensure safety it is necessary to choose an oil which will have an adequate viscosity when diluted.

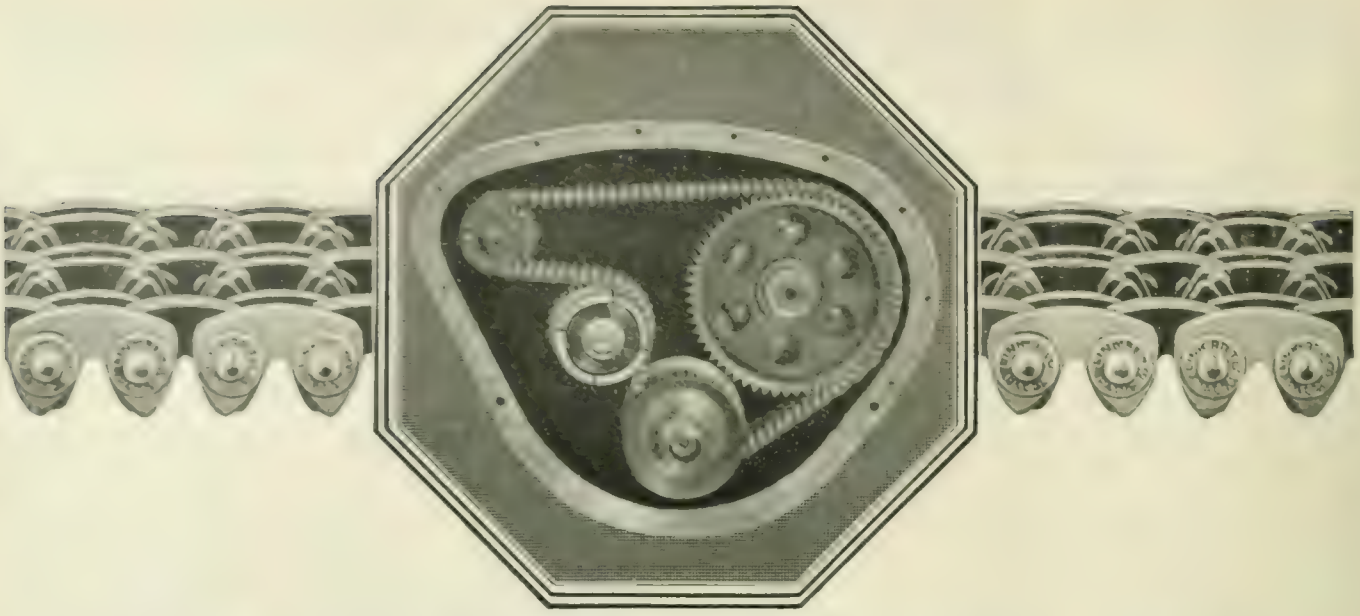
Adequate viscosity in an ordinary oil, containing cylinder stock, inevitably means excessive carbonization, and difficult starting in winter due to congealing of paraffin.

You can materially increase the factor of safety in the lubricating system by selecting the right type of Sunoco Motor Oil; and without fear of carbon or starting difficulties.

Accurate Lubrication is made possible with Sunoco through a choice of several types; each a straight run, wholly distilled lubricant. These several types offer a complete range of distinctive lubricants for every type of motor lubrication.

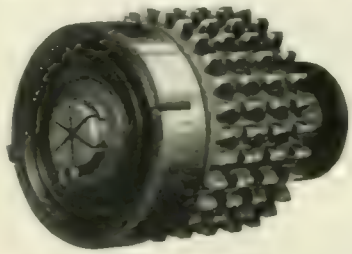
SUN OIL COMPANY, Philadelphia
Branches and Agents in Principal Cities

SUNOCO
THE DISTILLED OIL



A Triumph of Engineering Skill

Silence and efficiency in operation are the result of perfection in design, material and workmanship—



The Link-Belt
Automatic Chain Tightener
(*Vibration Dampener*)

A sweet-running quiet motor is a powerful sales argument. Any cost differential between the Link-Belt Silent Chain "Front-End" Drive and usual timing-gear sets is offset by ease of assembly in the factory, elimination of all "running in" and "matching" of gears, and reduction to a minimum of costly servicing and replacement.

THE car buyer's demand for a quiet-running engine was successfully met by the Link-Belt Silent Chain "Front-End" Drive with the effective Link-Belt Automatic Tightener—a distinct advance over all types of front-end drives.

The verdict of manufacturers, engineers and car owners, *based on actual tests,* is unanimous:

"The Link-Belt Silent Chain 'Front-End' Drive is noiseless when it starts and remains noiseless during its entire life".

There is no better guarantee than performance on the road. Mileage records of Link-Belt-equipped cars, as high as 76,000 miles (without need of "front-end" service), must be considered as the most valuable part of the Link-Belt guarantee as to the quality, efficiency and dependability of the Link-Belt Silent Chain "Front-End" Drive.

Our Engineers will work with yours to achieve a quiet motor.

LINK-BELT COMPANY, INDIANAPOLIS

1409

LINK-BELT

SILENT CHAIN FRONT END DRIVES

TL
1
S12
v. 13

SAE journal

Physical & Applied Sci. Serials

Engineering

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE